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**Supplementing grazing dairy cows with crops: fodder
beet and oats, to improve milk production and
nitrogen utilization**

A thesis
submitted in partial fulfilment
of the requirements for the Degree of
Doctor of Philosophy
at
Lincoln University
by
John Alabi Bozinviya

Lincoln University

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Abstract

Abstract of a thesis submitted in partial fulfillment of the requirements
for the Degree of Doctor of Philosophy

**“Supplementing grazing dairy cows with crops: fodder beet and oats,
to improve milk production and N utilization”**

by

John Alabi Bozinviya

The objectives of this research were to determine the impact of supplementing pasture-based diets with forage crops, previously used to mitigate winter N losses, on dry matter intake (DMI), milk yield, milk composition, and N utilization from dairy cows. Three supplementation studies integrating fodder beet (FB, *Beta vulgaris* L) or oats (*Avena sativa*) with perennial ryegrass (*Lolium perenne* L.)-white-clover (*Trifolium repens* L.) pasture were carried out in early or late lactation. Further, modelling studies were conducted to compare the effects of these crops on the productivity and profitability of irrigated dairy farms in Canterbury, New Zealand.

The aim of the first experiment was to determine the effect of FB or oats on dry matter intake (DMI), milk production and N utilisation of grazing dairy cows in early lactation. The experiment was a comparative study of four spring feeding regimes with sampling replication via animal (n = 12 cows/treatment). Forty eight early lactation dairy cows were fed 3 kg DM/cow/d of fodder beet, oats forage or oats silage as supplement +

18 kg DM/cow/d of pasture for 21 days using a completely randomized design. Total apparent DMI was greater ($P < 0.001$) for grazed oats forage (OF) and oats silage (OS) compared with pasture only (Control) or fodder beet (FB). Cows substituted pasture for supplement maintaining a similar metabolisable energy (ME) intake (226 ± 3) across treatments. Consequently, there was no effect ($P = 0.865$) of supplement on milk yield or milk solids yield ($P = 0.436$). However, supplementation with FB resulted in lower ($P < 0.001$) urinary N concentration (4.7 g N/L) compared with CON, OF and OS (5.9, 6.0 and 5.5g N/L) respectively. The higher urinary N concentration in CON, OF and OS is likely to be due to higher N intake (630, 725 and 657 g N/cow/day respectively) compared to FB (589 g N/cow/day). These results showed there was no increase in milk production due to high substitution rates and similar energy intake. However, low protein supplements such as fodder beet were effective at reducing N intake and improve N use efficiency for milk production. Questions remained regarding the animal response to FB or oats when supplemented to cows with a lower energy demand in late lactation.

The aim of the second experiment (autumn) was to determine the effect of FB or silage (ryegrass or oat) supplementation on DMI, grazing behavior, milk production and urinary N excretion on grazing dairy cows in late lactation. Fifty-four late lactation dairy cows were supplemented 4 kg DM of fodder beet (FB), oats silage (OS) or ryegrass silage (RGS) in addition to allocation of 12 kg DM/cow/d above 1500 kg DM/ha residual as perennial ryegrass and white clover pasture. The experiment was carried out over 21 days. Total DM intake was similar across treatments ($P = 0.69$), but milk production for cows supplemented with OS was lowest (1.01 kg MS/cow/day) compared with the RGS (control) or FB treatment that had similar milk yield (1.11 and 1.13 kg MS/cow/day respectively). The lower milk yield of OS compared with other supplements could be explained by the low ME of the supplement as well as the greater pasture mass offered to those cows. Autumn is an important time of the year to reduce N losses and supplementing with FB in late lactation reduced ($P < 0.05$) apparent N intake, milk urea N, (37, 40 and 44 g/dL) and spot urine N concentration (2.8 versus 3.9 and 4.0 g/L) compared to feeding OS or RGS respectively. These results demonstrated that cows on pasture offered low CP, and high-energy supplements,

such as FB, during late lactation can sustain milk production while lowering N surplus. Further considerations were needed to understand why no milk response to FB was observed and to determine whether the quality of the product (milk composition) alters even though the quantity (milk yield) does not.

In the third experiment, the purpose was to more clearly understand the lack of response in the first experiment by including grazing behavior measurements as well as the effect of milk quality. Thirty-six early lactation dairy cows were fed perennial ryegrass-white clover (control) and supplemented 3 kg DM of FB or OF for 21 days. Again, as with experiment one there was no difference observed in total DMI (16.1 ± 0.52 kg DM/cow/day) or milk solids yield (1.9 ± 0.8 kg MS/cow/d) between treatments. Cows in each treatment spent similar amount of time grazing (413 ± 38.5 minutes/cow/d). There were supplement effects on milk quality. Milk fat and lactose (%) increased by feeding FB. The increase in fat % appeared to be due to increased short chain fatty acids. Though FB reduced the more valued long chain, (and some medium chain) fatty acids compared with the RGS control. Milk protein % was unaffected by supplement, but feeding FB increased casein concentration along with the minerals calcium and phosphorus. This suggests that cows supplemented with FB in early lactation may have been Ca deficient. As with previous experiments, cows that were supplemented with FB had lower N intake and lower urinary N concentration (2.4 g N/L) compared with OF and CON (4.3 and 3.1 g N/L). This resulted in, FB cows having a higher N use efficiency (36.2%) compared with OF and CON (29.5 and 29.8%, respectively). Given that there were little apparent milk yield benefits to supplementing with FB or oats during these short term grazing studies, follow up questions arose regarding the economic value of trying to integrate winter crops on the milking platform.

To determine the feasibility and profitability of including winter supplements on the milking platform, results from experiments 1,2 and 3 were incorporated into a commercial decision support tool, FARMAX. Four scenarios were compared to a baseline farm system representing a Canterbury dairy farm. The scenarios were 1. Feeding FB only in spring, 2. Feeding FB (grazed) in autumn and drilling oats after

grazing FB, which is grazed in spring, 3. Feeding oat forage only in spring and the last scenario was feeding oat silage in autumn. The results of the simulation showed that FB & OF (Autumn & Spring) scenario had the highest milk production (460 kg MS/ha) compared to (422, 418, 440 and 436 kg MS/ha) for baseline, FB spring, OF and OS scenarios respectively. Also, FB & OF (Autumn & Spring) scenario had lower cost per kg MS (\$3.7 kg MS). The most profitable system at a \$6.00/kg MS was FB & OF (Autumn & Spring) scenario on the milking platform. Results showed that despite there being no difference in herbage diet quality, supplementing FB & OF (A & S), scenario increased total DM offered and consumed (6.2%), thereby increasing milk production with 8.3% compared to (-1.6, 4.1 and 3.2%) for FB spring, OF and OS scenarios respectively with FB spring scenario that had the lowest milk production. Resulting in an increase of 10.1% in the gross margin profit/ha for FB & OF scenario compared to (6.0 and 4.4%) for OF and OS scenarios with the FB spring scenario having the lowest.

In the short term grazing studies, supplementing pasture-fed dairy cows with FB or oats did not increase total DMI in early or late lactation due to high pasture substitution rates (SR) and similar energy intake. However, supplementing FB had effects on milk quality in both spring and autumn experiments. Only FB supplement lowered N intake (in spring) and improved N use efficiency for milk production as well as consistently lowering spot urine N concentration. Oats was more likely to reduce milk production when offered ensiled and may be more appropriate as a dry cow supplement. In both short term feeding and economic modeling, integrating FB supplement has value in sustaining milk production while lowering N losses in urine.

Key words: Forage crops, catch crop, dairy cows, milk yield, milk solid production, composition, grazing behavior, nitrogen utilization, urinary concentration, Farmax dairy pro, and modeling.

Dedication

To the memory of my beloved father (Alabi Bozinviya)

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Chapter 1 Introduction

1.1. Background

In New Zealand agricultural systems, pastoral practices occupy most of the land use, with grassland occupying over 52% of the land area. Sown pasture and forage species account for almost 10 million ha, most of which are introduced from other countries, and 3.5 million ha are based on indigenous tussock grasses (Valentine and Kemp, 2007). The proportion of forage crops relative to grazed pasture is very low by world standards (Valentine and Kemp, 2007). In 2016, there were 6.6 million dairy cattle in New Zealand. Of note, has been the rapid increase in dairy cattle population in the South Island. Between 2002 and 2016, South Island dairy cattle numbers increased by over 50% from 1.3 million to 2.6 million, although the increase has been less pronounced since 2014. While in North Island, dairy cattle population increased by almost 6% (3.8 to 4.1 million) within the same corresponding period (2002 and 2016) (Statistics New Zealand, 2017; Agricultural Production Statistics, 2016).

Pastoral systems in New Zealand mainly use perennial pasture species such as perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L), which are able to survive year round in most regions of the country. Nitrogen fixation by legumes, particularly white clover, is integrated with l grasses to contribute to the nitrogen requirements of the pasture. However, there has been a 300% increase in the quantity of nitrogen fertilizer used on farmland in New Zealand in the last decade (Gillespie et al., 2017). This has contributed to intensification and water pollution (Monaghan et al., 2007).

Most NZ dairy farms have developed a seasonal pattern of spring calving to achieve coordination between the demand and supply of feed (Figure 1.1). This synchrony enables cows in both northern and southern regions to calve in early spring (July and August) respectively, and milked until late summer or autumn, which is built upon

feed availability. When availability of feed is low, i.e a deficit in pasture supply, supplements are fed to livestock.



Figure 1.1 Seasonal pasture production and need for supplementation (DCANZ, 2015).

In pastoral systems, supplements are primarily utilized to support animals when there is feed shortage, especially in periods of feed deficit such as late summer and autumn. Supplements may also be utilized for the improvement of animal performance (Clark & Woodward, 2007; de Ruiter et al., 2007). The type of supplement used generally takes account of the expected milk response to supplement, the price of milk and the ratio for milk value: cost of supplements (Holmes et al., 2002; Holmes & Roche, 2007). In NZ, the predominant types of supplements used are forages (fresh or conserved) such as maize silage, pasture silage, hay, annual and perennial forage crops (*Brassica* sp., Lucerne; *Medicago sativa*, chicory; *Cichorium intybus*), as well as industrial by-products such as palm kernel extract (PKE). However, in all of these the preferred

method of pasture or forage conservation is in silage form as it ensures better quality feed especially during period of pasture shortage at a comparatively low cost (Holmes & Roche, 2007).

Currently a major concern for farmers is managing nutrient loss which, should nitrogen (N) loss become regulated, could affect the economic sustainability of the farm business. To date, low N crops such as fodder beet (*Beta vulgaris* L.) have been identified as a solution to reducing N loss, particularly in winter, compared with other high protein crops (Edwards et al., 2014; Higgs et al., 2013; Pacheco et al., 2010). However, when a high yielding crop like fodder beet is fed *in situ* to densely stocked cattle, as the most cost-effective way to feed this crop, nutrient loading onto soils is large. To off-set this nutrient load catch crops such as oats are sown into the grazed crop (e.g. fodder beet) area to mop up soil N (Malcolm et al., 2017). The timing of sowing - and subsequent feeding - of catch crop vary depending on when grazing of fodder beet is completed. Practically speaking, many farmers may not be able to sow oats until August or September when fodder beet is removed and machines can access the paddock. Flow-on effects of type of feed and timing of feeding on animal performance require more information so that farmers may improve management decisions to minimize/balance environmental impacts and profitability.

From an economic perspective, it is important to assess how these crops can be integrated into the farm system not just as an N mitigation tool, as well as a feed source for animals within the system. The interesting qualities/ characteristics of fodder beet is that it is high yielding forage crop usually fed to dry cows as winter grazing and as part of beef finishing system (Gibbs, 2014; Chakwizira et al., 2013). In early research, fodder beet was investigated as a feed for non-lactating cows (Roberts, 1987, Edwards et al., 2014), but farmers have recognized the value of feeding it as a supplement especially during the shoulders of lactation in spring and autumn when pasture supply is below demand. Compared to pasture and some crops, the high DM yields, as well as water-soluble carbohydrate and metabolizable energy (ME) contents make it a promising crop for cows during lactation.

There is limited research on the value of fodder beet as a supplement for lactating animals, and also limited information on how catch crops such as oats might be incorporated into the feeding system during lactation. The aim of this study was to conduct descriptive research that would provide information on the potential role of oats or fodder beet for early and late lactation dairy cows.

This thesis presents a series of experiments which measure dry matter intake (DMI), milk production, grazing behavior and N utilization of cows on forage (fodder beet) and/or catch crop (oat) in addition to pasture.

1.2. Research aims and objectives

The broad objectives of this study were to conduct field experiments to determine milk response and quality to fodder beet and oat supplements in early and late lactation. Determination of herbage utilization, apparent dry matter intake (DMI), substitution rate, grazing behavior, and N utilization will be used to explain variation in response. The impact at the farm system level will be explored through modeling farm scenarios using Farmax dairy pro as described by (Bryant et al., 2010).

Therefore, the hypothesis were:

- Milk production will be improved when either oats or fodder beet are fed in early lactation
- Milk production will be improved when either oats or fodder beet are fed in late lactation
- Nitrogen use efficiency will be improved with supplementation of low N crops
- Integrating fodder beet and oats on the milking platform are profitable options for farmers

Specific objectives were to:

- Evaluate the effect of supplementing pasture with fodder beet or oats on DMI, and milk production of early lactation dairy cows.

- Examine the effect of supplementing pasture with fodder beet or silage (grass and oats) on DMI, milk production, grazing behavior and N utilization in late lactation dairy cows.
- Determine the effect of supplementing pasture with fodder beet or oats on grazing behavior, milk quality and N utilization in early lactation.
- Determine the whole farm impact of integrating fodder beet and catch crop oats on animal performance and profitability using FARMAX modelling.

1.3. Thesis structure

This thesis consists of seven Chapters (Figure 1.2). Chapter 2 reviews the literature with particular reference to supplementation on the milking platform. The remaining Chapters report on 3 grazing experiments, using fodder beet and oats as supplements, on milk production, milk quality, grazing behavior and N utilization. While, Chapter 6 reports on Farmax modelling on milk production and profitability. Chapter 7 is general discussion and conclusion.

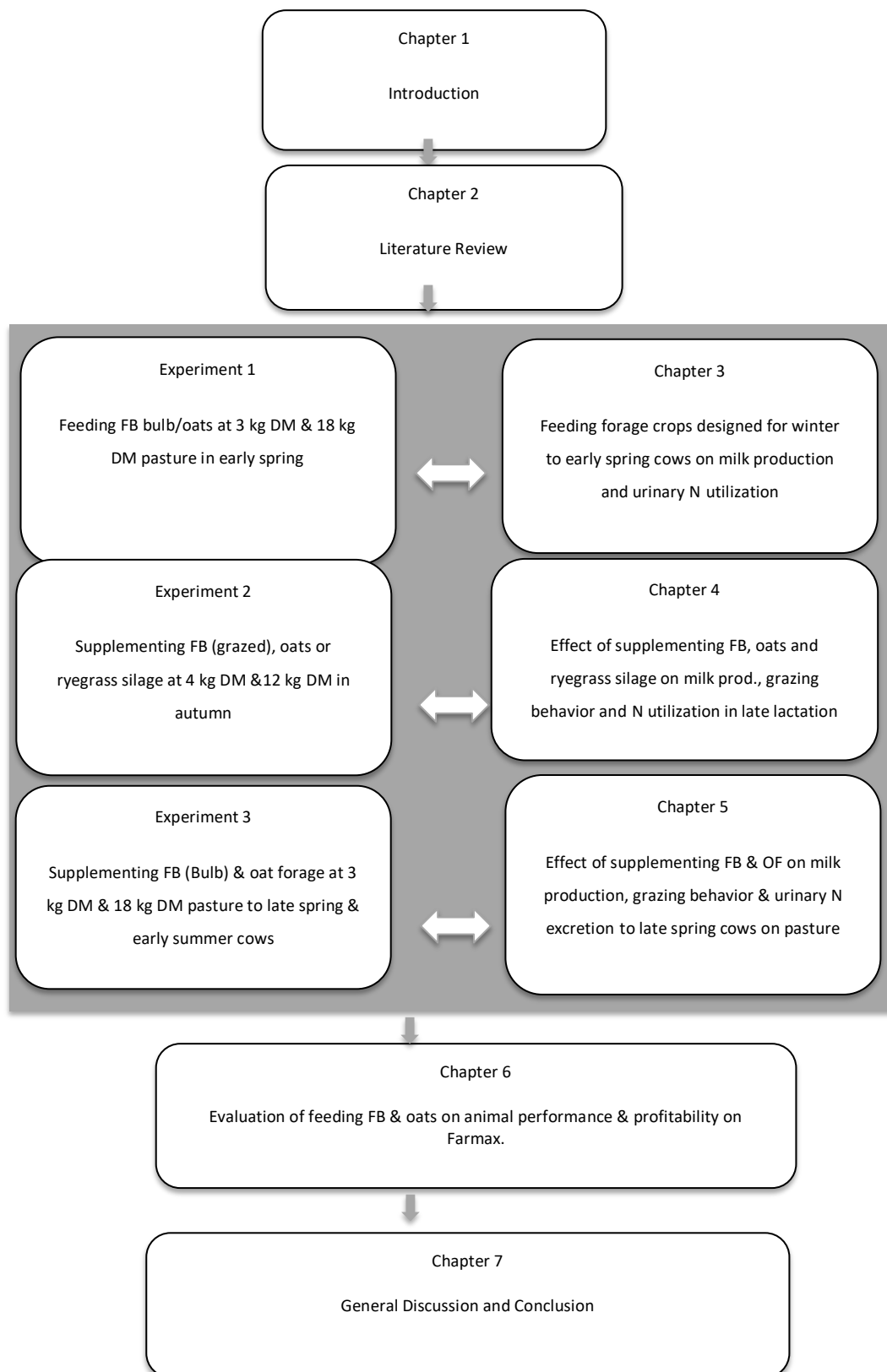


Figure 1.2: flow diagram showing thesis structure

Chapter 2 Literature review

2.1. The New Zealand dairy industry

The NZ dairy industry is made up of 11,748 dairy herds with 4,861,324 dairy cows (LIC, 2016/2017). During the season 2016/17, dairy companies processed 20.7 billion litres of milk containing 1.9 billion kg of milk solids (MS), (protein + fat). Total MS processed decreased 0.6% compared with the previous season (NZ Dairy Statistic, 2018). Since 1978/79, there have been declines in herd numbers at a rate of 176 herds per year. On the other hand, there has been an increase in average herd size over the last 30 seasons, which currently stand at 414 cows. In NZ an average dairy herd stocking rate is 2.81 cows/ha under an average 147 effective hectares. The average milk production stands at 4,259 litres per cow within 266 days in milk. The average dairy company payout for the 2016/17 seasons was NZ \$5.57/kg MS, and many farmers complete their long term financial budgets on a \$5-6/kg MS payout (Figure 2.1). Farmers in NZ do not receive subsidies from the government as many other countries do, so they must adopt practices that maximize profitability.

In order to operate a profitable farm business, dairy farmers must keep their operating costs low. As buying feed contributes a large proportion of farm costs, farmers can reduce costs by feeding a predominantly pasture diet. Such pasture-based systems rely heavily on the utilization of binary perennial ryegrass and white clover pastures. Typically, clover accounts for less than 15 percent of total annual DM in NZ dairy pastures, far less than the required 30 percent needed to capture the animal productivity benefits (Kenyon et al., 2017). Clover has high feeding value and also helps naturally in fixing N in the soil, which is why it is required in the pasture diet. Despite the fact that clover has the capacity to meet the N required by the pasture, the use of N fertilizer has grown in recent years. A decade ago NZ farmers applied N fertilizer at an average of 110 kg/ha/year (Valentine & Kemp, 2007). However, the current annual application of N fertilizer is between 150 to 200 kg N/ha (FertResearch,

2018). The use of N fertilizer has enabled farmers to synchronize feed supply and demand, though large quantities of fertilizer has also supported greater stocking rates.

2.1.1. FEED SUPPLY AND DEMAND

As a result of noticeable seasonality in pasture production and thus feed, virtually all farm activities follow a seasonal pattern to match the pasture feed supply with the feed demand (Holmes et al., 1987). In NZ, most dairy farms have adopted a system of seasonal calving. Under such pattern cows start calving in late winter in both the North and South Island. The justification of such pastoral livestock practices is to synchronize the period of high feed requirements with the maximum rate of pasture production on the farm (Figure 2.2). High stocking rate and spring calving are embraced so that maximum feed requirements coincide with maximum pasture growth (Penno et al., 1995). N fertilizer can be used to increase pasture production in spring. Slower pasture production in early spring raises the question of calving date and subsequently, days in milk, an important profit driver. Cows lactate until late summer or autumn, depending on feed availability, some farmers supplement to prolong lactation and increase days in milk at the end of the season.

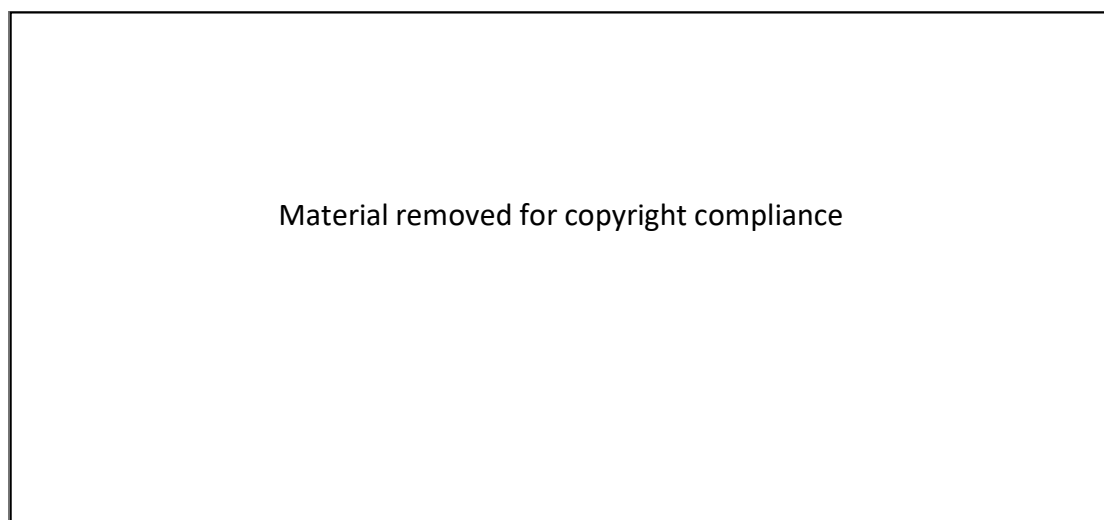


Figure 2.1: Typical pasture growth curve of NZ and mean NZ milk production per month (DairyNZ, 2018)

One of the common strategies the farmers have often adopted to increase feed availability and dry matter (DM) production is to integrate crops such as oat and low N forage crops such as FB on the milking platform, and such is done in anticipation of a period of feed shortage. Although previous research has investigated the DM yield of fodder beet and oats crops, there is less information on the nutritional value and subsequent milk response of lactating dairy cows to these crops.

2.1.2. TYPES OF SYSTEMS

In recent years, dairy farmers have used supplements to intensify their systems to enhance animal performance (milk yield, milk solid, BCS, live weight gain etc), profitability as well as reduce nitrate leaching. In New Zealand pastoral farming is about profitably balancing feed supply and demand, though a continuum exists for the quantities of imported feed farmers are prepared to use. Therefore, five (5) production systems have been described by DairyNZ. These range from system 1, characterized by all grass feeding systems, with no imported, to system 5 with 25-45% of imported feed. (DairyNZ Farmfacts, 2018).

A shift in farming intensity occurred from the 1990's which saw increasing number of farms move away from low towards higher input systems. Driven by cheaper fertilisers, access to irrigation, milk price etc. The consequence of these actions has ultimately led to degradation of the environment with greater nutrients being leached into waterways (Monaghan et al., 2008).

2.1.3. ENVIRONMENTAL IMPACTS

The NZ dairy sector is making great efforts to sustain global competition by reliably increasing its productivity and sustaining inputs use. The rapid growth of the dairy industry has remarkably increased the amount of N into groundwater and surface sources through leaching, Di & Cameron, (2002). N in soils is present as organic N, nitrate (NO_3^-) and ammonium (NH_4^+). As a result of the negatively charged soil particles and NO_3^- ion leading to nitrate being held off into the soil water and later leached during periods of drainage (Di & Cameron, 2002). Perennial ryegrass herbage

usually contains high crude protein (CP) (>16% N) that is more than required by lactating cows and the excess N is excreted in urine. Cow urination deposits approximately 700-1000 kg N/ha in the urine patch area, and this far exceeds pasture N uptake (Ledgard et al., 2006a). Silva et al. (1999) reported that there was leaching of about 12% urinary N to the soil and pastoral area received approximately 25% in urine patches annually. In the leachate it was observed that it contain higher nitrate-N concentrations compared to drinking water level required by the Ministry of Health (2008) of 11.3 mg N/L. Lately, it has been observed that many drinking wells have breached this health levels/standard particularly in Canterbury (Environment Canterbury, 2010).

Nitrate run-off into underground and surface water also posed serious threat to the ecosystem. One of the major threats is the enhancement of algae growth, resulting in decreased oxygen concentration in the water, which is injurious to aquatic life. More so, agriculture in NZ has led to the depletion of native biodiversity (via mutilation or harm of native habitat); it has also led to various contamination/damage of soil structure, soil erosion, as well as release of greenhouse gases (PCE 2004; MfE 2007; Clark et al. 2007; Jay & Morad 2007; Monaghan et al. 2007; Flemmer & Flemmer 2008; Moller et al. 2008). Due to such activities, the New Zealand dairy industry receives extensive public condemnation of its negative environmental effects. To manage the impact of farming, in particular dairy farming, on water quality, mitigation options are being investigated. As excess dietary N has led to increased N surplus being deposited in urine patches, farmers are using supplements to manipulate N intake and excretion.

2.2. Supplementation

In order to increase lactation length and yearly cow productivity on the milking platform dairy farmers use supplements to support pasture particularly at the beginning and end of lactation (Penno et al, 1999). Therefore, supplementation is a crucial component in grazing (pasture) system globally. New Zealand dairy farms show huge difference in the types of supplementary feeds used and this is reflected in contrasting features of each feed (de Ruiter et al., 2002). The feeding method has

an important effect on the utilization for a specific feed type. Information on common feeding methods was sourced from industry professionals. These methods are then used in determining feed utilization for each feed type. Also, the chemical composition of metabolisable energy and crude protein value varies among different supplement type.

The following are common supplements used in NZ, conserved forages (hay, pasture silage, maize silage) perennial and annual forage crops (Lucerne; *Medicago sativa*, Brassica sp., chicory; *Cichorium intybus*) and industrial by-products (palm kernel extract) (de Ruiter et al., 2007). Brassica and forage spp. (kale, turnips or rape, fodder beets and oats crops) are all crops that can be fed *in situ* and provide high quality feed which can be used to fill period of feed deficits.

2.2.2. SILAGES

Pasture silage

Traditionally, New Zealand dairy farmers use supplementary feeds (including pasture silage) during period of pasture deficit, constituting a small portion of the annual feed intake of cows. Silage production has been largely used to manage surplus pasture during spring, instead of producing high quality supplementary feed for lactating cows (Howse et al., 1996). Feed surpluses occur from late September to late December and sometimes in autumn, where excess pasture is conserved as silage. Average silage yield was 3500 kg DM/ha, with a scope of 2800 to 4300 kg DM/ha (Howse et al., 1996). Depending on the species and maturity of the pasture when ensiled, the nutritive quality of the silage is in (Table 2.1).

Maize silage

Maize for silage is grown mainly in summer and though it provides moderate levels of metabolisable energy (ME) it is low in protein (Table 2.1) and often more expensive than pasture silage. From a nutritional point of view, pasture is well complemented by offering a cheap energy source, and with good management, the quality of the

silage can be very consistent. Maize is generally good for metabolizable energy, protein, and starch to be of high levels and with lower levels of fibre. In most cases the nutritional value of maize silage are greatly determined by the cob:stover ratio. FeedTech analytical service (n=203) collected samples in 2000 and it shows that on average, nutritive quality of New Zealand maize silage has considerably increase in starch content, and a low reduction in protein content (Kolver et al, 2001). Depending on farm system, the use of maize silage as a supplement is both as a bought in feed or grown on farm. Nutritional composition of maize silage is shown on (Table 2.1).

Whole crop cereal silage

Cereals such as oats provide a significant quantity of feed for a single grazing between winter and early spring or as a conserved silage feed. Oats can be drilled in February for early-winter grazing, through to April – May in mild climates for late-winter grazing. They (oats crops) are also known to thrive between maize crops and harvesting for green silage in early spring (September), because they have the capacity to produce up to 44% more than annual ryegrass when the crop is at full canopy closure phase (de Ruiter et al., 2009). The crop are harvested, ensiled and used as supplement mostly during period of feed shortage. Nutritional composition is shown in Table 2.1.

Alternatively crops such as barley are drilled later between September and early October (spring) for whole-crop silage. It takes short time to mature compare to triticale. It is preferred because other crops cannot be drilled until mid to late spring, or in dryland climates.

Table 2.1. Yield and nutritional composition of various silage types

Silage type	Yield	DM	OM	CP	WSC	NDF	ME	Reference
	(t DM/ha)	(% of FW)	(% of DM)	(% of DM)	(% of DM)	(% of DM)	(MJ/kg DM)	
Pasture	21-22	36.1	89.5	15.4	6.4	48.4	9-11.1	DairyNZ farmfacts, 2018
Maize	21-24.5	36.1	96.0	7-9	3.1	40.9	10-11	Morris et al., 2016
Oat	7-11	36.7	93.8	8-11	16.0	56.5	9-10.2	de Ruiter et al., 2002
Barley	5-8	34.7	94.5	6-10.5	5.1	47.7	9-10.5	MPI, 2017
Triticale	14-20	42.4	93.5	9.3	7.6	54.0	9.9-10	MPI, 2017
Pea	8-12	34.2	90.1	11-15.6	5-7	46.9	9-10.8	Corbett et al., 1995

Where DM= dry matter; OM= organic matter; CP= crude protein; WSC= water soluble carbohydrate; NDF= neutral detergent fibre; ME= metabolizable energy.

2.2.3. CROPS

Forage brassicas

One of the benefits of forage brassicas over perennial ryegrass (*Lolium perenne* L.) is that they have the ability to thrive well in cooler temperature than the latter as well as produce large quantity of quality dry matter (DM) especially in winter.

Kale (*B. oleracea*)

A survey carried out among farmers growing kale crops in Canterbury, showed that DM yield of kale for dry land crops was 5 t DM/ha compared to irrigated crops stand at 17 t DM/ha (de Ruiter et al., 2002; Judson & Edwards 2008). Peak yields for forage cereals at the same period stand between 5-8 t DM/ha (de Ruiter et al. 2002) and ryegrass yield is between 3-4 t DM/ha (Paramenter & Boswell 1983). The nutritive value for kale is quite high. For instance, the digestibility is consistently between 85-90% (depending on cultivars), with metabolizable energy (ME) content of 11-13 MJ/kg DM and CP content of between 15-25% (Valentine & Kemp 2007). In spite of the high nutritional value of kale, the crop contains anti-nutritional agents. The nitrate concentration in kale is between 1 to 2% of DM, which is high. According to Smith (1980), it also contain up to between 0.4 to 4.0% of S-methyl cysteine sulphoxide (SMCO) and thiocyanates (0.10 to 0.15%) that might inhibit nutritive value and can also cause haemolytic anaemia in the rumen during fermentation and decrease DM intake in sheep (Barry & Manley 1985). The fibre content of kale crop is low (neutral detergent fibre (NDF) 18.0-48.2% DM and acid detergent fibre (ADF), 14.3-34.1% DM), high levels of non-structural carbohydrates (WSC), (30.7-44.6% DM) and a relatively low dry matter percentage of 13-18% (de Ruiter et al., 2007).

Swedes

Swedes can thrive well under in cool and moist environments. For peak yield and high quality winter feed, kale crop is sown in late spring (November) through early summer (December), and can produce yield up to 20 t DM/ha under favorable conditions (de Ruiter et al., 2009). Swedes have high digestibility when fed as whole plant and with proper grazing practices, high utilization is achievable. The crop can be sown alongside rape (3–4 rows of swedes: 1 row of rape) to increase CP content in a winter crop (de Ruiter et al, 2009). See Table 2.2 for nutritional composition.

Table 2.2. Nutritional composition (means and range) for fresh green crops

Crop type	DM (% of FW)	OM (% of DM)	CP (% of DM)	WSC (% of DM)	NDF (% of DM)	ME (MJ/kg DM)	Reference
Kale	17.2	91.3	13.1	38.7	27.1	12.5	Judson & Edwards, 2008
Swedes	10.4	89.8	11.9	48.1	21.3	12.4	De Ruiter et al., 2010
Fodder beet	21.2	96.1	5-13	61.0	26.5	12-13.5	Gibbs, 2011
Forage oat	14.5	90.4	17.2	15.7	41.8	11.8	De Ruiter et al., 2000
Triticale	16.0	90.1	18.2	15.3	44.3	11.2	MPI,2017

Where DM= dry matter; OM= organic matter; CP= crude protein; WSC= water soluble carbohydrate; NDF= neutral detergent fibre; ME= metabolizable energy.

Fodder beet

Significant numbers of dairy farmers in South Island feed their pregnant, non-lactating dairy cows off the milking platform, on several instances on local mixed cropping farms. Fodder beet (*Beta vulgaris* L.) along with oats is one of the major forage diets as it fits well into crops rotation sequence systems, and maintains high quality diets at dry matter (DM) yields exceeding 10 t DM/ha (Judson et al., 2010).

Fodder beet allows farmers to produce in excess of 20 t/DM/ha of feed for animals to consume during winter and spring, when feed availability is most critical. This highly digestible energy makes fodder beet effective for maintaining or increasing stock performance by complementing other feeds with lower energy and more fibre. The typical FB crop will be 20-25% DM of leaf and 75-80% DM of bulb, <10% crude protein (CP) bulb and >15% CP leaf, and 25-30% neutral detergent fibre (NDF) (Edwards et al., 2014). The bulb has low CP and NDF with high sugar, so is palatable and rapidly fermented in the rumen (Table 2.2). As a consequence, the transition to FB crop by cows must be carefully managed to avoid rumen acidosis (Gibbs, 2011).

The fodder beet crop has been largely cultivated in Canterbury as an energy diet with yield greater than 12.5 t DM/ha (Gibbs, 2013).

Forage oats

Forage oat can be grazed by ruminants (Arelovich et al., 2003; Bargo et al., 2001). Grazing dairy cows on oat pasture are generally supplemented with protein to increase milk production and stocking rates (Garcia et al., 2000). Supplementation also helps to correct for changes in the amount (i.e increasing total DMI) and quality (i.e increasing the energy and protein intake) of pasture. The use of oats as an energy supplement has been shown to increase average daily gain of beef heifers. The composition of oat forage depends largely on the time and stage of grazing. However, it averages 16% DM, 90.4% OM, 16.2% CP, 15.7% WSC (de Ruiter, et al., 2006).

In Canterbury, research has shown that 28 t DM/ha is achievable with forage cereals in a year (MPI, Technical paper, 2017/53). Same period were pasture production average 21 t DM/ha/yr (DairyNZ 2018) under irrigation. In most part of South Island forage oats is the principal winter cereal crop because it has the ability to withstand extremely low temperature and produce high-quality feed compare to dormant pastures at that time. Most farmers depend largely on oats to feed cows and feedlot programs utilize forage oats as well especially in autumn and early spring (Forage oats variety guide, 2017).

2.2.4. GRAINS/BY-PRODUCTS

Palm kernel expeller (PKE)

Palm kernel expeller (PKE) is a byproduct of oil palm. It is widely used as supplement for dairy cows to fill short-term herbage shortage and according to MAF (2007), over 350,000 tonnes of PKE was imported into New Zealand during 2007. Within the last 10 years, dairy farmers use of PKE in NZ has increased substantially with over 30% rise in imported feed (MPI, 2017). PKE fed with restricted pasture allowance was able to increase the amount of milksolids produced daily (Dias et al., 2008). PKE has become popular as a result of being cheaper than many other supplements, also it has a considerable CP of 16.6%, NDF is 73.6%, ADF of 40.7% (Dias et al., 2008). The nutritional and chemical composition as well as digestibility percentage is shown in Table 2.3.

Maize grain

The utilization of maize grain as supplementary feed in the dairy industry no longer continues to grow, averaging between 40,000 to 50,000 tonnes DM/ season over the past 25 years (MPI, 2017). Within the last 10 years, dairy farmers in NZ have enhanced by increasing stocking rate and producing more milk/cow. The demand for feed/ha has gone up at an alarming rate than the feed supply from pasture and this has some consequences, there has been a paradigm shift from total pasture to a system that accommodate and systemically uses supplementary feeds. Maize grain has an organic

matter of 98.8%, NDF of 13.8%, ME is 13.6 and ADF 1.9% (Mackle et al., 1999). The nutritional composition is shown in Table 2.3.

Barley grain

Barley cultivation remained constant for the past two and half decades. However, the use of barley as supplementary feed for dairy cows has increased especially in the South Island (MPI, 2017). Barley grain substantially increased feed intake and was used to increase fat-corrected milk by only 0.1 kg when fed as supplement to lactating dairy cows (Opatpanakit et al., 1993). Barley grain nutritional composition is captured in Table 2.3.

Table 2.3. Nutritional composition for grains and by-products

GRAIN/BY-PRODUCTS TYPE	DM	OM	CP	SSS	NDF	ME	REFERENCE
	(% OF FW)	(% OF DM)	(% OF DM)	(% OF DM)	(% OF DM)	(MJ/KG DM)	
Maize grain	89	89.8	8-10.9	48.1	9.0	13.6	Kleinmans et al.2016
Palm kernel expeller	90	91.3	13.2	38.7	63.3	11-12	MPI 2017
Brewer's grain	27.3	92.9	24.1	8-11	49.3	10-11	Ewings, 1998
Wheat grain	89	97.4	11.3	15.7	14.8	11-14	De ruitter et al., 2000
Barley grain	89	90.1	11.2	15.3	21.3	12.2	Kolver, 2000 & pioneer, 2019.

Where DM= dry matter; OM= organic matter; CP= crude protein; SSS= soluble sugar or starch; NDF= neutral detergent fibre; ME= metabolizable energy.

2.3 Milk response to supplementation

Typically cows respond to supplements through an increase in dry matter and energy intake. However, variation in response to supplements can be caused by a number of reasons but the key drivers include,

- Wastage of supplement – utilization can differ between supplements depending on method of feeding and infrastructure.
- The decline in pasture intake or substitution that arises when supplements are fed
- Energy that is not directed to milk yield – e.g. used for reproduction or body condition. Analysis on cow production over the past 10 years (2004-05 to 2013-14) reveals an increase in per cow production of 20% (LIC & DairyNZ, 2015), while feed costs have risen over 100% (DairyNZ, 2015).
- Nutrient composition. DM intake (DMI) response is rarely influenced by the particular nutrients mixture provided by the (Penno et al., 2006).

However, the animal's short and long-term milk yield responses may be affected by effects of both the food deficit imposed on the cow, and the specific nutrients provided by the supplement, those on DMI responses. Factors such as pasture (herbage allowance, herbage quality and substitution rate), season, stage of lactation, cow's energy balance, supplement amount, supplement type, timing of the feed supplement and cow's genetic strain, can strongly determine the animal total response to the feed supplements (Gregorini et al., 2010a; Horan et al., 2005; Khalili & Sairanen, 2000; Peyraud & Delaby, 2001; Stakelum, 1993; Woods et al., 2005).

There is little scientific data measuring milk production when using fodder beet. In overseas studies, Phipps, Sutton and Jones (1995) found milk yield per cow increased by 12.6% compared with a solely grass silage diet, when fodder beet made up 33% of the diet, this was due to a 23.7% increase in total daily DM intake when fodder beet was included. Few studies on the supplementation of fodder beet when fed with pasture during lactation of grazing dairy cows, demonstrates that fodder beet can be used to maintain milk production in early lactation, and milk and body condition score

on late lactation. In experiments in which fodder beet have been offered at 4 kg DM/cow with a basal ration of pasture silage (*ad-libitum*), milk concentrations of both fat and protein, as well as milk volume have increased (Fisher et al., 1994). Muller et al., (1994) also reported similar changes in milk composition when fodder beet replaced grains, while Birkenmaier et al., (1996) reported a small increase of milk fat concentration and small and inconsistent changes in milk protein concentration.

However, other studies have shown no effect of fodder beet supplementation on milk yield in spite of increased DM intake (Roberts 1987; Fleming et al 2018). Given the popularity of this crop, more information is required on the effect of feeding fodder beet on the dairy platform to lactating cows. Studies have shown that energy intake is the first factor limiting milk production in good quality ryegrass/clover pasture-based systems. Also, the type of energy supplementation can have an effect on the milk response of grazing animals. Fodder beet is made up of sucrose, whereas other low N supplements such as maize and cereals store carbohydrates as starch. A study by Mogensen and Kristensen (2003) comparing fodder beet and barley showed a lower milk yield from cows fed FB in spite of similar DM intake. Roger and Robinson, (1981), examined the response of cows to forage oat supplements which covered the whole of lactation and the results showed the responses during the treatment averaged 0.5 L/kg DM oats and scope from 0-0.9 L/kg. Forage oats depressed fat concentration with an average response of 17 g fat/kg DM of oats, (scope 0-33).

The use of feed such as by-products and maize silage can serve as alternatives sources of energy to cows grazing pasture with comparatively high fibre content. It has been observed that in NZ, due to the high prices of conventional/traditional energy sources farmers have resorted to the use of energy sources such as by-products (brewer's grain, whey, molasses and PKE) as well as maize grain for supplements. Large variations exist in the composition of by products and whether or not they are effective in supporting milk yield. For example, sugar cane residue such as molasses which is fed during spring in NZ, has shown no production benefit when fed alongside pasture diets in spring unless cows are under-fed (Clark and Woodward, 2007). The utilization of palm kernel extract (PKE) has also increased significantly as supplement

fed to cows within the last few years. One of the most common supplements used in NZ is maize silage (Kolver et al., 2001). Stockdale (1995) reported higher milk responses when maize silage was fed to cows on low grazing allowances of poor quality pastures. However, the milk response of feeding maize silage was negative when fed with high quality spring pastures under high allowance. Bargo et al., (2003) showed that responses in milk production to maize silage supplementation depend on the pasture allowance, milk production may be lower to/or similar at high herbage allowances, but at low herbage allowances milk production may be higher than the unsupplemented cows. Huber et al. (1964) and Davison et al. (1982) found that milk production increased with corn silage supplementation when pasture availability was restricted. However, others found that milk production decreased when corn silage was supplemented (Al-Marashdeh et al 2015; Bryant and Donnelly 1974).

Penno, McGrath, Macdonald, Coulter, and Lancaster (1999) found that when maize grain at 1.2 t DM/cow was fed as a supplement, the MS response was 98 g/kg DM. Comparatively for two seasons and on a farm-let, pasture silage supplements and rolled maize grain was investigated. Supplementation resulted in 82 and 88 g milksolids (MS)/kg DM respectively.

Several grazing trials indicated that crops such as oats and fodder beet can increase dry matter yield on New Zealand dairy farms. This trend will enable higher stocking rate for increased overall milk production. Whether this strategy will translate to increased overall profitability is less certain.

2.3.1. PARTITIONING OF ENERGY

Cows in early lactation partition considerably more digested nutrients toward milk production than live-weight gain compared with cows in late lactation (Broster and Thomas, 1981; Stockdale et al., 1987; Stockdale and Trigg, 1989). Energy Partitioning between body reserves and milk production and consequent carry-over effects might be responsible where little milk response is observed due to supplementation (particularly in early lactation), (Penno et. al., 1995a). Greater responses due to

supplementation have been recorded in mid and late lactation cows compared to early lactation cows (Stockdale, 1999).

However, in spite of the fact that health and reproduction is affected by energy balance, until recently, in breeding programs, milk production traits is aggressively selected by most dairy farmers (Migiior et al., 2005), with less consideration for other than traits. This has led to a situation referred to as homeorhesis, a condition where cows readily mobilizes energy to support (Bauman & Currie, 1980; Roche et al., 2006), only regaining lost condition when energy surplus to pregnancy, maintenance and milk production is consumed.

2.3.2. UTILIZATION OF SUPPLEMENT

Several researches have shown that different reasons could be responsible for supplement utilization. Timing of supplementation had been reported to affect DM intake that ultimately affect the level of utilization and milk production (Adams 1985; Hess et al., 2002; Sheahan et al., 2013). Also, high levels of utilization can be achieved by different methods of grazing management (Bryant, 1990a). Physical factors, such as soil type and stocking rate, rainfall prior to and during grazing/feeding (Smetham, 1973; Holmes and Dine, 1992). Other factors that might affect supplement utilization are feed quality and nutritive value (palatability) Gibbs (2011).

2.3.3. SUBSTITUTION OF PASTURE

When cows on pasture are supplemented, pasture DMI usually reduces with increasing supplement intake, a situation referred to as substitution rate (SR) (Kellaway and Porta, 1993). SR is one of the key reasons that defines the difference noticed in milk response (MR) to supplementing grazing dairy cows (Kellaway and Porta, 1993; Stockdale, 2000a). There are usually negative relationships that exist between SR and MR. When there is large SR, leading to little or no increase in total DMI, there is always low MR. In the short term, milk response is used to determine farm profitability via supplementation when compared to the prices of supplement

and milk. There is a close relationship between SR and MR, as such factors that influences these variables are discussed together.

Generally, supplementing with forage crops results in high SR compared to supplementing with concentrates (Mayne and Wright, 1988). Stockdale (2000a), reported that at any level of herbage intake, concentrate supplements tends to have lower SR than supplements from fibrous sources. Reduction in grazing time is often linked to high SR in forage supplements, perhaps because of the bulk properties associated with some forage supplements (Stockdale, 2000).

2.4. Challenges in the current pastoral system

Milk solids production and profitability of New Zealand dairy farms is tightly linked to the amount of herbage harvested by the grazing animal (Holmes et al. 2007). The supply of feed for dairy cows the single largest component of dairy farm operational costs. The primary source of home grown feed is grazed perennial pastures. The majority of dairy systems in New Zealand use perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) pasture which are normally grown in a simple binary mixture (Charlton et al. 1999). The predominant use of perennial ryegrass-white clover pastures reflects desirable characteristics of these species. The pasture is easy to establish, high yielding in fertile soils, has complementary growth pattern to seasonal animal demand and is tolerant of a wide range of environments and grazing management (Kemp et al. 1999). A typical perennial ryegrass-white clover pasture under irrigation on a Canterbury dairy farm can produce 21 t DM/ha/yr (DairyNZ 2017). However there are some limitations to perennial ryegrass-white clover pastures.

Production from perennial ryegrass-white clover pastures has become highly dependent on N fertiliser inputs and supplementary irrigation. Further, pasture quality can be low in perennial ryegrass-white clover in late spring and early summer when cows are in peak lactation (Burke et al. 2002). The pasture is also susceptible to the attack by a range of insect pests including grass grub (*Costelytra Zealandia*) and Argentine stem weevil (*Listronotus bonariensis* syn *Hyperodes bonariensis*)

(McFarlane 1990). These limitations can result in reduced feed supply leading to sub-optimal dietary intake and reduced milk production, accelerating the rate of decline in post peak milk yield (Holmes et al. 2007). Of particular concern is the role perennial ryegrass-white clover in N losses from a system. Reliance on N fertiliser inputs contribute to a high protein content of perennial ryegrass-white clover pasture that is above the requirements of the grazing animal. Nitrogen in excess of animal requirements is excreted predominately in the urine where it is easily leached through the soil profile and into waterways.

2.4.1. THE URINE PATCH

2.4.2.1 Urine composition

Nitrogen (N) concentration in the urine of ruminants varies from less than 1 to over 20 g N/L (Whitehead 1995; Dijkstra et al. 2013). A meta-analysis by Selbie et al. (2015) of published data found the average urinary N concentration of dairy cattle grazing grass pastures to be 6.9g N/L. However there can be a large variation between animals, even when grazing the same pasture type. Nitrogen in urine is contained in several N compounds and urea constitutes the highest proportion. Nitrogen also exists in the urine in ammonia, creatine, allantoin, creatinine and hippuric acid. The proportion of each compound can change depending on the diet of the animal.

Typically, as N intake increases, the proportion of urinary N present as urea increases (Petersen et al. 1998). According to Jarvis et al. (1995) urea contributes 90% of urinary N for cows grazing heavily fertilized grass based pastures. The proportion of total N as urea can show diurnal variation, with greater proportions in the morning than evening (Petersen et al. 1998; Bryant et al. 2013).

There are two important factors that influence urinary N. Kebreab et al., (2002), the first is N intake that drives the amount of surplus N relative to an animal's requirement. Secondly, water intake effects urinary N concentration due to its influence on both volume and frequency of urination. There is a linear relationship between N intake and urinary N output with increased N intake resulting in greater N

losses via urine. However, increased N intake does not necessarily relate to increased urinary N concentration. This is because there tends to be an increase in water intake for animals grazing higher N diets, which in turn results in greater urine volumes thereby diluting urinary N concentration but increasing overall urinary N output. This has been seen by Van Vuuren et al. (1997) who reported a 74% increase in urination volume following a change from low to high N diets with only a 0.2 g N/l increase in urinary N concentration. This highlights the importance of understanding not only the urinary N concentration, but also the amount of urine produced.

2.5. Role of supplements in environmental mitigation

In the South Island of New Zealand, forage crops are often used (grazed *in situ*) to winter off the milking platform most pregnant, non-lactating dairy cows (Judson et al. 2010). The objective is to try and regain the lost body condition during previous lactation (Edwards et al. 2014). However, the high stocking rate used to graze the high yield crops during the winter feeding period can result in large nitrate leaching losses relative to total farm footprint (Monaghan et al. 2007), and mitigation strategies need to be developed. Both the N concentration of each urine patch and the number of urine patches are important factors determining nitrate leaching (Li et al. 2012)

Using low protein supplements to increase dietary N use efficiency, avoiding an excess of CP available in the rumen, and increasing the energy supply to help converting dietary N into microbial protein may provide that opportunity to mitigate negative environmental impacts. Nitrogen utilization can be improved by including high energy, low protein supplements into the diets of grazing dairy cows (Hristov and Journy, 2005; Pacheco et al., 2008). The low concentration of N in urine evident for cows grazing fodder beet and kale is most likely related to the low overall N intake of forage and supplement (range 241-281g N/day), with the lack of difference between treatment reflecting the small difference in overall N intake (Edwards et al., 2014). Studies have shown that nearly 72% of N intake was excreted in faeces and urine, with milk urea N recovering an average of 25% as well (Kirchgeßner et al., 1994). Therefore, it is clear that one of the ways to mitigate environmental damage by N

leaching from dairy cows is to nutritionally reduce N intake by the animals. Reducing dietary N intake appears to be the most important factor in improving N utilization when ME intake is the same (Higgs et al., 2013). The concentration of N in urine for fodder beet was low relative to other studies for pasture-fed cows in early and late lactation (Pacheco et al., 2010, Bryant et al., 2014). In turn, this is likely to contribute to lower potential leaching losses from each urine patch (Malcolm et al., 2014), and may help offset the high urine patch coverage expected when dairy cows graze high yielding forage crops (Edwards et al., 2014).

Excreted fecal N in dairy cows is reported to be rather static in proportion to dry matter (DM) intake, estimated to be 7.5 g/kg DM ingested according to (Peyraud et al. 1995) or dietary dry matter (DM) intake of 0.6% (Van Soest, 1994). Faeces are made up of undigested feed N, undigested microbial N and endogenous N (Tamminga, 1992), but decrease in faecal N excretion doesn't seem to provide a reasonable way to accomplishing meaningful decrease in N loss from animals (Tamminga, 1992; Van Soest, 1994). Reasons being that feed protein true digestibility in most dairy cows ration is high, also microbial protein digestibility is high (Tamminga, 1992). Kirchgeßner et al. (1994) and Bequette et al. (1998) estimated that overall not more than 0.30 dietary N is utilized for milk synthesis throughout lactation cycle. About 0.29 was utilized for milk synthesis when grass silage and whole crop wheat based diets were used (Sutton et al., 1998a,b) and when a part of the grass silage was replaced with maize silage it increased to 0.32 (Cammell et al., 1999). Soluble carbohydrates tended to decrease total UN excretion and MUN as well as decrease urinary urea N excretion. Although starch and WSC in pasture diets have shown promise in reducing urinary N excretion (Edwards et al 2007) uncertainty exists over whether diets high in sucrose (eg FB) will be effective in reducing N loss.

2.5.1. Recent indoor and outdoor studies on the effect of feeding fodder beet on productivity and environmental implications

A number of recent studies have examined the effect of fodder beet feeding on milk production and nitrogen excretion in urine (e.g. Waghorn et al. 2018; Dalley et al.

2019). The indoor study of Waghorn fed fodder beet at 65% with pasture silage or fodder beet at 85% with barley straw to non-lactating dairy cows. The key was that mean urinary excretion was lower (52.0 (SE 5.8) g/day) in cows fed fodder and straw compared to fodder and silage (87.7 (SE 5.9) g/day) diet. An outdoor study of Dalley et al. (2019) with late lactation dairy cows fed fodder beet at 25% with pasture (11 kg DM/cow/day) and fodder beet at 40% with pasture (9 kg DM/cow/day) compared to control cows offered pasture (11 kg DM/cow/day) with maize silage (4 kg DM/cow/day). The key result was that, fodder beet (25%) treatments increased milk solids (MS) production (1.10 kg/cow/day) vs (1.02 kg/cow/day) for Control treatment. Fodder beet in the diet at 40% reduced urinary N concentrations (2.5 g/L) compared to (3.6 g/L) control (Maize), but this came at the expense of MS production when compared to fodder beet at 25% inclusion.

2.6. Whole farm systems and modelling

Previous sections in this review have referred to both long and short-term responses to supplements. In pastoral grazing systems such as occurs in NZ the dairy operation is often thought of as two parts relating to lactation and the 'dry period' which occurs through the winter when pasture supply is limited. Dairy wintering describes the management approach of feeding dairy cows between drying off in late May until calving for the following season in August (Monaghan, 2012). A successful wintering system is a component of the farm system that is crucial to the overall success of the whole dairy farm system (Cottier, 2000; Pinxterhuis, Dalley, Tarbotton, Hunter, and Geddes, 2014). With calving usually commencing in August, a healthy environment for the growing foetus over winter must be maintained (Cottier, 2000). A common goal of farmers is for cows to gain half a BCS during the wintering period (Judson and Edwards, 2008), with many cows being dried off at a BCS of 4.5 and a target of a BCS of 5 going into calving as BCS is correlated with milk production, reproduction, animal health and welfare (Kay, 2014). If a wintering system fails to support these activities, it may have significant negative impacts on the farming business as a whole, in terms of animal health and welfare, production and profitability.

The traditional New Zealand wintering systems are based on a low cost approach in order to maximize profitability. In the North Island, in regions such as Northland, Waikato and Taranaki, adequate pasture growth is maintained through the winter. This allows the majority of cows to be wintered on pasture and feed supplements (Dalley, 2014). In the South Island, in areas such as Southland and Canterbury, adequate pasture growth cannot be maintained due to low temperatures (Dalley, 2014) therefore the majority of dairy farms winter cows on spring (summer) sown forage crops (Tarbotton, Bell, Mitchelmore, and Wilson, 2012). Many cows are wintered off the milking platform at a substantial cost that equates to 20-25% of the annual farm working expenses in Southland (Cottier, 2000). Given the large costs associated with feeding during the winter, and throughout the rest of lactation, determining the most efficient use of feeds can have a large impact on the whole farm system.

Consideration of whole farm systems (WFS) is an integrated approach of the different components adding to the entire farm (Kelly & Bywater, 2005). Such components include the land productive capacity and labour availability as well as financial resources. The WFS concept prioritizes the complex relationship between factors. Modification to any factor may alter entire productivity in several ways. Individual element can be classified into inputs, outputs and the environment (Kelly & Bywater, 2005). One out of the cardinal reasons of the system is to achieve profit that is both sustainable (economically and environmentally) for the future.

Pasture-based agro-ecosystems farms are complicated, consisting of many aspects such as soil, weather, animals, plants, humans (managers and labour), economics and machinery. Animals, plants and soil have critical organic methods such as cycling of nutrients and growth stage that control how they operate and relate with other components (Jones & Luyten 1998). Economic aids are use in making decisions by manager, management decisions are implemented using machinery and labour. Each components of the pastoral farm have been studied in detail. Despite this, construction of farm let studies, which is used to determine the interactions of all the components in the agro-ecosystem are fundamentally difficult to construct.

Coordinating knowledge of the organic processes into pastoral farm agro-ecosystem models permits ample store of information on each aspects (animals, soil, plants, management) to be directly implemented to enhance the management of commercial farming enterprises (Black 1995). A pastoral farm agro-ecosystem system provides a channel to evaluate a number of contrasting scenarios before farmlet studies starts on the most successful plan, thereby reducing costs (Hart et al. 1998). Models such as Farmax dairy pro, Overseer, whole farm model (WFM), agricultural production system simulator (APSIM), urine patch framework (UPF) etc have been used in several applications in forecasting animal responses from plant data measured in small plots (Boschma & Scott 2000), forecasting animal performance as well as pasture production at different sites recording 50-100 years of daily weather data (Clark et al. 2003), testing hypotheses and deducing immeasurable parameters (Bywater & Cacho 1994) and estimating within-year and year-to-year variations, and theoretical minimum and peak pasture growth, nitrogen leaching and drainage (Bryant et al. 2007).

2.7. Conclusions

Forage and catch crops, such as fodder beet and oat are a critical aspect of the winter diets of non-lactating, pregnant (dry) dairy cows in southern New Zealand. Fodder beet is an important winter crop because it is capable of producing high >20 t DM yields of better quality forage (ME and CP if grazed). On the other hand, oat crop grow well and help mop up excess N deposit when drill after fodder beet compared to perennial ryegrass in late autumn and winter period. However, performance and profitability of dairy cows on FB or oats on the milking platform have not been fully examined because;

1. There is little data on MR to FB or oats supplementation on grazing dairy cows.
2. Also, what management strategies/technique is available to reduce milk production losses during transition.

3. Despite the perceived advantages of supplementing FB or oats to grazing dairy cows on the milking platform, there is a need to understand how its use might influence the whole farm system from an environmental aspect by reducing urinary N excretion.
4. There is a need to use systems models to examine how FB or oats can be incorporated into farm systems (on long-term basis) and whether it can be profitable. Owing to the fact that the grazing experiments are short-term.

Chapter 3

Effect of supplementing pasture with fodder beet or oats to early lactation dairy cows

3.1. Introduction

Land use for dairy production has increased by 44.5% over the past 20 years (Ministry for Primary Industries Technical Paper, 2017). As a result of high commodity price for dairy products and co-operative initiatives to improve farm productivity, intensification of land use on dairy farms has also increased. The rise in cow stocking rate has not been accompanied by a similar rise in conventional pasture production, rather feed supply is managed through buying in feeds or leasing or purchasing land for grazing of crops during the winter. Historically the crops fed to livestock during winter were brassica's such as kale, but the protein content of these crops resulted in high urinary N losses (Edwards, et al. 2014). Instead high yielding, cheaper and low N crops such as fodder beet (FB) have been adopted as the primary winter-feed source as FB has lower N loss compared with kale (Edwards et al, 2014). The N losses from dairy winter systems using FB are further reduced by subsequent sowing of catch crops such as oats to utilize excess soil N (Malcolm et al 2017). Oats can be sown after in situ grazing of FB is complete, though greater environmental benefits have been observed from earlier sowing of oats which requires lifting of FB from the ground to allow access to machinery. While lifted FB can be stored and fed out to lactating cows, the best use of the oats catch crop is uncertain or not well investigated.

In commercial practice consideration needs to be given to management of these feeds and how they may affect animal productivity and pasture management when used as supplements. Supplementation can increase and sustain milk production, however, it is the type of supplement given as well as pasture quality that determine responses

(Bryant & Trigg 1982; Holmes 1987; Woodward et al., 2002). Slow pasture growth rates in spring and autumn also mean that some form of supplement will be required to manage rotation length and pasture accumulation. The continued feeding of FB in early lactation aids metabolic transition from this crop onto pasture. Consequently many farmers are choosing to sow small areas of the milking platform into FB. But there remains the question of how to manage the oats catch crop, as the rapid growth of this crop can create unplanned feed surplus and farmers are uncertain whether to graze or ensile oats in spring. Review of the literature (Chapter 2.0) highlighted the insufficient information on milk response to supplements such as FB or oats. Answers around animal response to these feeds and practical considerations to feeding are sought. Types of supplement in pastoral systems influence substitution for pasture, particularly when animals are not restricted. Increasing DM allocation during a feed surplus may increase voluntary feed intake, or reduce pasture utilization, or both. The purpose of this research was to investigate the short-term effect of supplementing pasture-fed dairy cows with oat forage, oats silage or fodder beet on pasture utilization, milk production, and N efficiency for milk production.

3.1.1. HYPOTHESIS

This study will test the hypothesis that incorporating fodder beet, or oats forage (conserved and grazed respectively) into the farm system (milking platform) will improve dry matter intake and milk solids production compared to a pasture only diet.

3.1.2. OBJECTIVES

The aim of this research is to

- Determine the effect of feeding fodder beet or catch crop oat in addition to pasture on dry matter intake (DMI).
- To evaluate the effect of supplementing fodder beet and catch crops on milk production and N utilization.

3.2. Materials and methods

3.2.1. EXPERIMENTAL SITE AND DIETS

The experiment was carried out at the Lincoln University Research Dairy Farm (LURDF) New Zealand (43°38'S, 172°27'E) with approval by the Lincoln University Animal Ethics Committee (AEC, Appln #640). The experiment was a comparative study of four spring feeding regime with sampling replication via animal ($n = 12$ cows/treatment) and time ($n = 14$ day measurement). The treatments feeding regime included a pasture only control. The control diet (CON), which was offered to all treatments, consisted of a perennial ryegrass and white clover pasture offered at 18 kg DM/cow/day above 4 cm pasture residual height.

To ascertain if voluntary intake could be increased by supplementation, an additional 15-18% DM was allocated as supplement (3 kg DM/cow/day) compared with CON. The supplements were: fodder beet (FB) bulb, oats forage grazed *in situ* (OF) and oat silage (OS). The FB was harvested from a winter block at Ashley Dene Research and Development Station, on the 6 September 2015 and stored in windrows 2.5m high and 6m wide until the study commenced. Oats (var. Milton) were direct drilled into 1.5 ha at LURDF on 3 August 2015 at 100 kg seed/ha. Excess oat cultivated at Ashley Dene Research and Development Station (ADRDS) July ending was harvested into oat beilage from the winter block on 3 November, 2014. In practice oats would follow the FB crop towards the end of winter-feeding program and the remaining FB would be lifted and stored and fed to lactating cows.

3.2.2. ANIMALS AND MEASUREMENTS

A total of 48 high-producing Friesian × Jersey crossbred multiparous cows were selected from a larger mob and allocated into four groups which were similar in age (5.5 ± 3 years), milk solids production (2.53 ± 0.5 kg MS/cow/day), days in milk (66 ± 2 days) and live weight (509 ± 14 kg LW). Prior to the trial, diets consisted solely of

ryegrass and white clover pasture, requiring an adaptation period of increasing supplement by 0.5 kg DM every two days.

Prior to the experimental period, cows had a 7 days adaptation period to acclimatise to diets, management and herd structure. The measurement period commenced on the 27th October and finished on the 9th November 2015. Each day the supplemented groups (FB, OF and OS) were allocated their supplement at 0900 hr and after two hours were moved to their pasture allocation at 1100 hr. The CON group was offered a new pasture allocation at 0900 hr. All pasture allocations were back-fenced and, for OS and FB groups, supplement was fed out in troughs on the previous days' allocation area. As a result, the OF group had greater walking distance than other groups as they grazed oats forage in situ and were moved between supplement and pasture each morning.

Each day supplement intake was determined by weighing offered and refused (FB and OS) or harvesting samples of pre and post graze mass (OF). Prior to feeding, the FB was chopped with machete and fed to cows in a trough. Allocation area of forage oats was based on available forage mass above 6 cm. Subsamples of each supplement were collected for determination of DM% and nutritive content. Cows have daily access to drinking water (*Ad libitum*) in the pasture area.

Individual milk yield was recorded daily using an automatic milk recording system (De Laval Alpro herd management system, De Laval, Tumba, Sweden). Two milk sub samples were collected for all cows every 3 days at a.m and p.m milking and analysed for fat, protein and lactose concentrations (Livestock Improvement Corporation, Hornby). Milk urea N was measured for milk samples collected during the last week of the trial, the sub samples were skimmed after centrifuging and the skim milk analyzed by automated Modular P analyzer (Roche Hitachi, Basel, Switzerland) by an enzymatic assay as described by Talke and Schubert, (1965).

Urine and dung samples were collected twice in the final week of the study from spot samples following am and pm sampling (procedure described by Totty et al, (2013).

Urine was analyzed for total N, urea-N and ammonia and faecal samples was analyzed for total N by combustion method.

Urinary g of N/d = $21.9 \text{ (mg/kg)} \times \text{BW (kg)} \times 1/\text{urinary creatinine (mg/kg)} \times \text{urine N (g/kg)}$

3.2.3. FORAGE MEASUREMENTS

Pasture compressed height was measured pre and post grazing using rising plate meter (Jenquip) to estimate pasture mass as $\text{kg DM/ha} = 140 \times \text{RPM reading} + 500$. Group apparent intake (kg DM/cow/d) was determined as the difference between pre and post grazing pasture mass divided by the area and number of animals. Apparent N intake was determined using the same method but used the N concentration in herbage and supplements pre and post feeding.

Pasture herbage samples were collected for DM content and chemical analysis (approx. 1 hr) before and after grazing each sampling day. Herbage was sampled to soil level, and a subsample was weighed, oven dried and reweighed for DM determination. A second sub sample (50 g FW) was sorted to leaf and stem for determination of diet selection. The remaining sample was freeze-dried, ground and chemical composition analyzed. Chemical analysis for pastures and supplements was performed by near-infrared spectrophotometry (Feed and Forage Analyzer, FOSS Analytical, Hillerod, Denmark)) for ADF, NDF, crude protein and dry matter digestibility (DMD) determination (Van Soest, 1991), also ground samples of FB were assessed for N: Elementar (Variomax CN Analyser, Elementar Analysensysteme, Germany), ADF, NDF (Van Soest et al. 1991), ash and WSC (Pollock & Jones 1979).

Metabolizable energy content was calculated using the modified ADF (MADF) equation where $\text{ME (MJ ME/kg DM)} = 14.55 - 0.0155 \times \text{MADF}$ (CSIRO, 2007).

Sub samples of supplement were collected each sampling day (every 3 days), quick-dried in a microwave to provide an approximate measure of DM content (Microwave oven method. a microwave oven with a rotating platter (Carousel). These values were used to calculate how much fresh weight of each supplement was required to supply

3 kg DM/cow/d. Sub samples were also collected each sampling date and freeze dried for near infrared spectrophotometry (NIRS) to determine the chemical composition of herbage and Oats, while FB samples were supported by wet chemistry to determine ADF, NDF (Van Soest et al. 1991), ash and WSC (Pollock & Jones 1979).

During the measurement period the quantity of supplement refusals after 24 hours was collected, weighed and sub-sampled for determination of DM content. The daily supplement intake (kg DM/cow/d) on the supplemented treatments was then calculated. Oat forage yield cut was carried out twice every week prior and during the trial by the use of 0.5m² with 2 cuts at 6m apart, and sub sample oven dried at 65^o for 24 hours to determine DM % and subsequent yield DM/ha.

3.2.4. STATISTICAL ANALYSIS

The mean of milk, urine and faeces for each treatment were determined using data from each measurement from animal samples over sampling days. DM Intake and herbage measurements were determined as means for the treatment group as animals grazed together in their treatment groups. The effect of pasture type on milk, urine and faecal measurements was analyzed for variance using GenStat 18.1 (VSN International LTD), with cows as random effect and pasture type as fixed effect using a one-way ANOVA. Herbage measurements were also analysed by one-way ANOVA using Genstat with sampling day as the replicate. All means were separated using Fishers protected LSD test at the 5% significance level

3.2.5. RESULTS

PASTURE COVER AND QUALITY

Pre graze pasture mass was similar ($P = 0.58$) for all treatments but supplementation increased ($P < 0.001$) post grazing residuals (Table 3.1). Relative to pasture, FB had low levels of protein and fibre and high sugars while OF had the highest protein and OS had the highest fibre content. The FB sample resulted in highest ME concentration while the high fibre content of OS contributed to low digestibility and low ME content.

Table 3.1. Composition of pasture, and supplements: fodder beet (FB), oat forage (OF) and oat silage (OS) offered to cows in early lactation.

Items	Pasture	FB (Bulb)	OF	OS	SEM	P Value
Pasture pre- mass (kg DM/ha)	3326	3180	3231	3156	236	0.58
Pasture post- mass (kg DM/ha)	1571 ^d	1775 ^b	1875 ^a	1653 ^c	16.3	<0.001
Neutral detergent fibre (g/kg DM)	401 ^c	122 ^d	462 ^b	582 ^a	11	<0.001
Acid detergent fibre (g/kg DM)	233 ^c	66 ^d	262 ^b	328 ^a	0.25	<0.001
Crude protein (g/kg DM)	228 ^b	98 ^d	264 ^a	99 ^c	6	<0.001
Water soluble CHO (g/kg DM)	240 ^b	595 ^a	213 ^c	112 ^d	2.1	<0.001
Metabolisable energy (MJ/ kg DM)	11.0 ^c	13.5 ^a	12.5 ^b	9.5 ^d	0.07	<0.001
DM (%)	17.1	20.7	19.8	33.6	16.6	<0.001

SEM is standard error of the mean. Means with different superscripts are significantly different, $P < 0.05$

Dry matter intake and milk production

Cows offered supplement had lower pasture intake (Table 3.2). Substitution rates (kg less pasture DMI relative to the control/kg of supplement consumed) were 0.85, 0.65 and 0.31 for FB, OF and OS respectively. Cows offered OS had greater pasture intake than cows offered FB or OF, but cows grazing OF had greater supplement intake. Consequently, total DMI was highest for cows in OF and OS groups ($P < 0.001$). Cows were at peak lactation and producing high milk solid yield of 2.48 kg MS/cow/day. In spite of variation in DMI, differences in ME content of diet resulted in similar ME intake and no difference in milk yield (Table 3.2). Apparent ME intake was highest for OF, and this led to numerically more milk solids yield. Also throughout the period of the study, no difference ($P = 0.526$) in live weight was detected among treatment group.

Nitrogen use efficiency

Apparent N intake was greatest for cows in the OF treatment and lowest for cows in the FB treatment (Table 3.3). Similarly MU, urinary N and urea concentration were greatest for cows with high N intake and lowest for cows in FB with low N intake. Fecal N concentration was greatest for cows fed FB compared with cows fed other supplements (Fig. 3.3). Low apparent N intake and similar milk N resulted in a higher NUE for FB compared with other treatments.

Table 3.2. Apparent intake, milk yield and milk composition of cows grazing pasture only (CON) or offered fodder beet (FB), oat forage (OF) or oat silage (OS) in early lactation.

Items	CON	FB	OF	OS	SEM	P Value
Pasture intake (kg DM/cow/d)	17.3 ^a	15.0 ^b	14.0 ^{bc}	16.4 ^a	0.18	<0.001
Supplement intake (KgDM/d)	-	2.7 ^b	5.1 ^a	2.9 ^b	0.10	<0.001
Total intake (Kg DM/cow/d)	17.3 ^b	17.7 ^b	19.1 ^a	19.3 ^a	0.18	<0.001
ME intake (MJ ME/cow/d)	224 ^b	223 ^b	232 ^a	223 ^b	1.70	<0.001
Milk yield (litre/cow/d)	26.4	26.2	27.0	26.1	0.75	0.865
Milk fat (%)	5.58	5.81	5.91	5.69	0.25	0.579
Milk fat (g/cow/d)	1.48	1.52	1.57	1.48	0.78	0.551
Milk protein (%)	3.62	3.74	3.72	3.63	0.09	0.439
Milk protein (kg/cow/d)	0.95	0.98	0.99	0.94	0.03	0.816
Milk solids (kg/cow/d)	2.43	2.50	2.56	2.42	0.09	0.436
Live weight change (kg)	-1.44	2.30	3.10	-1.01	12.2	0.526

SEM is standard error of the mean. Means with different superscripts are significantly different, $P < 0.05$

Table 3.3. Effect of supplementing fodder beet (FB), oats forage (OF) or oats silage (OS) on apparent N intake, milk urea N and spot urinary and fecal N composition and N use efficiency (g milk N/g N intake)

	Pasture	FB (Bulb)	OF	OS	SEM	P value
N intake (g/cow/day)	630 ^c	589 ^d	725 ^a	657 ^b	9.31	<0.001
Milk urea N (mg/dL)	40.1 ^b	32.2 ^c	46.8 ^a	41.2 ^b	0.35	<0.001
Urine N concentration (g N/L)	5.90 ^a	4.70 ^b	6.00 ^a	5.50 ^a	0.35	<0.001
Fecal N%	3.51 ^b	3.68 ^a	3.58 ^b	3.58 ^b	0.07	0.002
N use efficiency	0.236 ^b	0.261 ^a	0.214 ^b	0.224 ^b	0.55	<0.001

3.3. Discussion

3.3.1. INTAKE AND MILK PRODUCTION

The results of this study showed that fodder beet was no more effective than oats, either ensiled or grazed in situ, for improving milk production in early lactation. These results are in agreement with the findings of Fleming et al., (2018) who also found no MS response to fodder beet supplementation when fed to grazing dairy cows. The reason for lack of milk response in both this study and that of Fleming et al. (2018) appear to be due to high pasture substitution rate (SR). In the current study variation in substitution rate for each supplement resulted in similar apparent ME intakes for both the FB and OS treatment compared with the CON. When offered poor quality silage, cows maintained ME intake by being more selective from pasture as the pasture residuals were increased compared to the control. Fodder beet on the other hand is high in quality, and cows maintained ME intake by consuming less pasture.

One of the hypothesis of this study is that in peak lactation, which occurs mid spring, pasture is typically leafy and contains high protein content, and supplementation with

high ME fodder beet was anticipated to improve milk yield relative to the more fibrous oats. Grazing dairy cows fed high fermentable CHO and high ME supplements has the ability to capture more N released in the rumen, thus increasing milk yield (Cosgrove et al., 2007). On high quality forage diets animals can eat as much as 4% of their body weight (Micheal & De Vries, 1995), under this study the cows consumed up to 3.6% of their body weight. The total DM intake in this study showed that the oats supplemented treatment groups were able to increase their intake above the CON treatment. Though the lower ME content of these feeds particularly the OS did not result in greater ME intake.

The high pasture SR for the FB cows might be attributed to the source of energy (fermentable carbohydrates) provided by FB diet, which can decrease ruminal pH, thereby reducing the activity or number of cellulolytic bacteria, which ultimately will negatively affect the rate of fiber digestion of pasture (reduce hunger and motivation to eat), and off course herbage dry matter intake (Dixon and Stockdale, 1999). Supplementing with sucrose has previously been reported to decrease rumen pH and decrease the rate of NDF digestion (Huhtanen and Khalili, 1991; Chamberlain et al., 1993). In this study the nutritional composition of FB shows that it contain high WSC contents (Table 3.1). Diets with high concentrations of sugars or starch promote shifts VFA profiles and lead to greater lactate and propionate acids (Dijkstra et al., 2012). Previous researches have measured the performance of volatile fatty acids (VFA) on satiety and hepatic oxidation and findings shows that infused propionate, but not acetate or butyrate (Oba and Allen, 2003; Knapp et al., 1992), reduced dry matter intake. Oba and Allen (2003) ruminally infused propionate and the outcome shows that there is direct reduction in size of meal between 2.5 to 1.5 kg DM as propionate increased. Elliot et al. (1985) separately infused acetate and propionate into the mesenteric vein, and the result revealed reduction a reduction in DMI when propionate was infused, with no effect on acetate. The sugar content of the FB supplemented diet may well explain the reduction in appetite and high substitution rate.

Both pasture only (CON) and FB supplementation had better feed conversion efficiency (140 g MS/kg DM apparently eaten) compared with oats (approx. 130 g MS/kg DM apparently eaten). The mean accumulated milk yield was 571 kg per cow over a 3 weeks early lactation period (21 days), which did not differ between control and supplemented treatments – in spite of those cows consuming an average of 3.6 kg supplement (especially oat treatments) per day. This gave a marginal milk response to supplements of 0.0 kg milk/kg consumed which is considerably less than the 1.72 kg milk/kg of silage (oats and barley) supplement as reported by (Khalili et al., 2002). The response would likely have been improved if pasture allowance was less in supplemented groups (Dillon et al 1997). Feeding supplements comes at a cost to the farmer, both in the cost of feed, the capital equipment to feed it and the labour. In addition to not realizing a milk response to feeding supplement, the additional cost is reduced pasture utilization that may reduce feed quality in subsequent grazing cycles. More so, there should be a synchrony between oats sowing date and supplementation period, because the quality of the crop largely depends on the stage it is grazed. In this study, the oats crop was sown in June and grazed in mid September, and at that stage of grazing the crop is more stemmy compare to if grazed in August. Although, weather and soil moisture conditions need to be taken into consideration. To enhance DMI and milk response through supplementation, timing of supplementation was reported (Sheahan et al., 2013) as well understanding physical and soil conditions (Smetham 1973).

3.3.2. EFFECT OF SUPPLEMENT ON N UTILIZATION

The low CP content of FB resulted in improved N use efficiency that can help reduce N losses. Studies using non-lactating cows which compare fodder beet with kale or other moderate protein feeds have previously shown that FB reduces urinary N (UN) excretion (Jonker et al., 2017). Several studies have reported the concentration of N in urine to be directly related to N intake (Tas et al. 2006b; Higgs et al. 2012). Selbie et al., (2015), reported an average urinary N concentration of dairy cows grazing herbage to be 6.9g N/L. However, there can be huge difference when grazing cows are supplemented high water soluble carbohydrates in early lactation (Jonker et al.,

2017). Not a surprise, in this study a reduction in N intake coupled with similar milk protein production resulted in greater NUE for the FB group compared with other treatments. Although it is generally regarded as a positive outcome if N losses are reduced, for high producing cows in early lactation feeding low N feeds may result in protein deficiency. Milk urea can sometimes be used to indicate protein deficiency, generally a high producing pasture fed cow in early lactation would have MU level in the range of 25-40 mg/dL (DairyNZ, 2017). In the current study the mean MU was generally at the upper end of this range, especially the OF supplement group the MU was above the desired range.

Earlier we speculated that the sugar content of FB may have lowered pH and reduced fibre digestion equally it can be argued that insufficient protein would have a similar effect. Unlike in urinary N losses largely attributed to N intake, the fecal N result shows that FB had highest content of N compared to other treatments despite having the lowest N intake. In NZ, it is known that a typical grass contains more than 200g CP/kg DM (Holmes et al., 2002). In this study, with CP concentration exceeding 260g/kg DM for OF treatment is the reason urinary N concentration was high despite consuming less kg DM of feed compared to OS cows. The high CP content of both CON (220g CP/kg DM) and OF (260g CP/kg DM) reported in this study is in agreement with that of Clement et al., (2016), that feeding grazing dairy cows crude protein content above the range of (180-200g CP/kg DM) is well higher than what the cow need and will likely increase urinary N concentration.

On the other hand, the NUE was high in the FB treatment with over 9.5% compared to control treatment and 18% compared to OF respectively, possibly because of the high water soluble carbohydrate in the FB diet. This is in agreement with Hristov and Journy, (2005); Pacheco et al., (2008), who reported that nitrogen utilization can be improved by including high energy, low protein supplements into the diets of grazing dairy cows.

Practically, offering forage oats as a supplement in early lactation (September – November) may be hampered by opportunity to follow a FB crop as a result of wet soil conditions. It is more likely that forage oats will be available for grazing during

peak lactation (from November) when there is already a pasture surplus. During a feed surplus period, quality of pasture can be low as a result of seed head, so questions arise regarding the value of high quality supplements during a feed surplus. Can milk production be improved and what is the overall economic value to the farm system?

3.4. Conclusions

These findings indicate that pasture is likely to be spared if farmers use winter crops in early lactation to aid transition. Given that oats silage was poorer quality than other supplements, feeding low N, ensiled oats in autumn (during feed shortage and for N loss mitigation period) may offer a more practical solution for the use of this catch crop, than feeding in situ in peak lactation. More so, results of this study show that the high SR resulted in no net improvement in milk production. However, the results on N utilization shows that FB can be used to mitigate urinary N loss during peak lactation as there was 20% reduction compared to pasture (control) only treatment.

Therefore, it is advisable that measurements on grazing behavior and extra measurements on milk composition as well as replicating treatments be captured in subsequent experiments.

Chapter 4

Effect of supplementing fodder beet and silage (grass and oats) on milk production and N utilization in late lactation dairy cows

4.1. Introduction

In the pasture-based dairy systems of New Zealand, supplements are commonly fed in autumn to sustain DMI (White, 1982), milk production and permit pasture substitution to manage herbage height on the farm as winter approaches. But most times, the capability of transforming feed to milk solids tends to reduce in autumn when compared to spring (Stockdale & Trigg, 1989).

Autumn has been identified as a critical period for reducing nitrate leaching as it precedes a period of high drainage and slow plant growth to retain soil N (Dinnes et al., 2002). Studies have shown that supplementing low N feeds have the ability to dilute the quantity of grazed nitrogen (N) in a diet of predominantly ryegrass-clover herbage, thereby decreasing overall N intake and, possibly the concentration of UN excreted in dairy cows on pasture (Bargo et al., 2003; Castillo et al., 2000). The low crude protein (CP) content of FB and oat may be an efficient mitigation method to reduce N leaching from animal N excretion (Edwards et al., 2014; Gibbs, 2014).

In Chapter 3 fodder beet, oats silage and oats forage were fed to peak lactation (spring-calving) cows to determine effects on DM intake, milk production and N utilisation. Those results showed that feeding FB or oats influenced DM intake, but there was no response on milk yield, or composition. The N utilization was relatively high in spring due to high metabolisable protein demand, and we would argue that low N feeds such as FB are far more pertinent in late rather than early lactation. Protein demands for production are decreased,

yet pasture is often high in protein in autumn. Feeding a low N supplement may decrease the concentration of protein in the diet and reduce N intake. In the previous study, FB feeding reduced apparent N intake and urinary N concentration, which has implications soil N loading from urine in autumn. The repeatability of this N reduction results will be tested again in the current study - relative to more conventional silages, which also typically have low N. Finally, the research will compare the effect of supplementing FB (versus ryegrass baleage or ensiled oats) on DMI, milk production and N utilization in late lactation dairy cows.

4.1.1. HYPOTHESIS

This research will test the hypothesis that supplementing late lactation cows with FB will maintain or improve milk yield and reduce urinary N losses through lower N intake compared with supplementing with ensiled ryegrass or oats.

4.1.2. OBJECTIVES

- To determine effect of supplement type on DM intake.
- To ascertain the effect of supplementation on MS production and composition.
- To determine the effect of supplements on N utilization.

4.2. Materials and methods

4.2.1. EXPERIMENTAL SITE AND DESIGN

The experiment was carried out over 21 days between 18th April and 7th May 2017 at the Lincoln University Research Dairy Farm (43°38'S, 172°27'E). The experimental site is under irrigation over a predominantly Templeton sandy loam soil type. The experiment was a completely randomized design with three supplement treatments and three replicates. Supplement treatments included a control of conventional ryegrass silage (RGS), and wintering regime supplements: oat silage (OS), or fodder beet (FB) all of which were offered

at 4 kg DM/cow/day with a base pasture allowance of 12 kg DM/cow/day above 3.5 cm compressed height.

Pastures for the experiment consisted of perennial ryegrass (cv. Arrow) diploid, with ARI, LE (endophyte) having +7 days (heading date) and white clover (cv. Kopu II). Perennial ryegrass-white clover pastures were established in March 2014 and herbage mass was controlled by regular grazing. Pastures were prepared prior to the experiment by staggering grazing of experimental pastures over a three weeks period (Figure 4.1). Nitrogen fertilizer was applied at rate of 20 kg N/ha after each grazing. Pasture was well irrigated and all paddocks contained a mobile water trough where cows had access to clean drinking water.

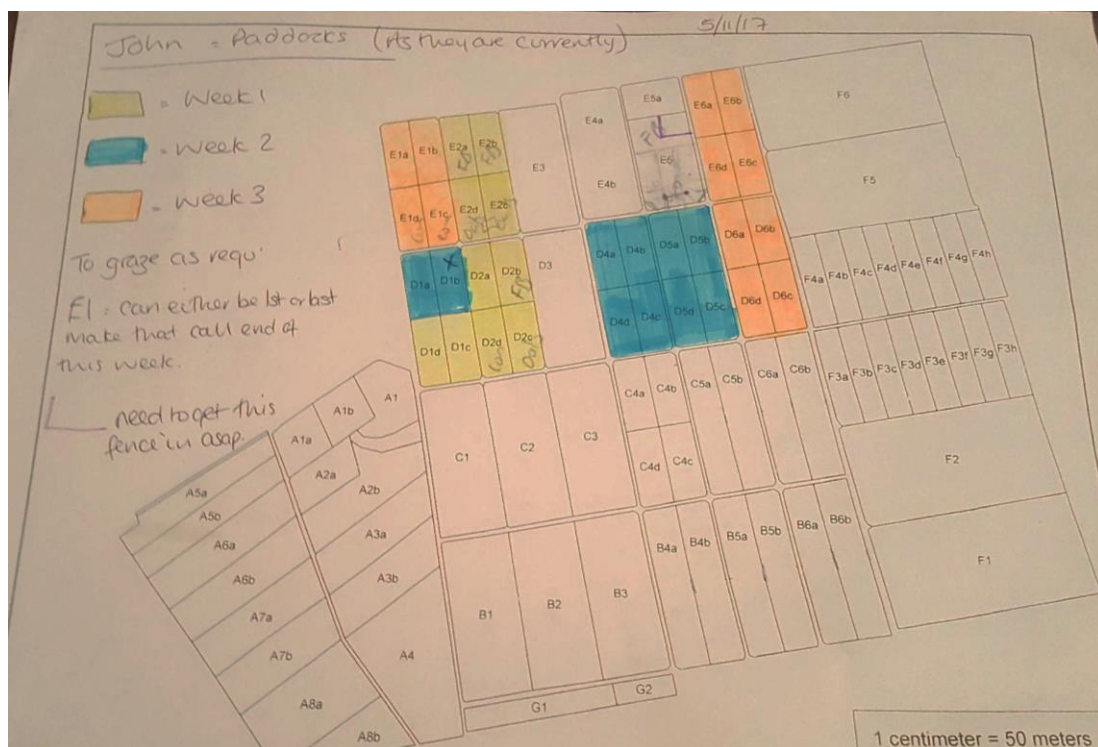


Figure 4.1. Lincoln University Research Dairy Farm (LURDF) map showing paddocks grazed during autumn experiment. Shaded and colored areas showed grazing on weekly basis.

Following cultivation, 0.5 ha fodder beet seed (cv. Rivage) was drilled on 10 October 2016, using a spacing of 45cm rows, at 80,000 seeds/ha. Nitrogen fertilizer at 50 kg N/ha was

applied at emergence, and a second application of N fertilizer and lime was applied earlier at 1 t/ha to improve soil pH.

Oats silage (cv. Milton) was sourced from a crop sown at Ashley Dene Research and Development Station in July, 2016. The oats whole crop was harvested at the chessy dough stage (30-40% DM) for silage on 21 November 2016 and ensiled in a stack. The ryegrass silage was harvested at a pre grazing mass of 3400 kg DM to post grazing height of 1500 kg DM and ensiled after 24 hours wilting on the 12th December, 2016 at the Lincoln University Research Dairy Farm (LURDF).

4.2.4. ANIMALS AND MEASUREMENTS

Experimental animals were selected from a larger mob of cows grazed together during a two weeks covariate period prior to the experiment. From those animals 54 mixed age, pregnant, Friesian x Jersey dairy cows were blocked into nine groups based on milk production ($1.54 \pm .4$ kg MS/cow/day), live weight (495.1 ± 54 kg LW), BCS ($4.4 \pm .3$), age (5.3 ± 2.3 years) and days in milk (238.3 ± 13 days). The nine groups (6 cows/group) were randomly allocated to one of the three treatments.

The experiment took place over 21 days period with the first 7 days of an adaptation phase followed by a 14 days measurement period. Adaptation to supplement occurred by increasing allocation by 1 kg DM every 2 days until all animals were offered 4 kg DM/day of their supplement. Cows were milked twice daily at 0600 and 1400 hr. Following the morning milking cows were offered supplements. Oat silage and grass baleage were fed out to cows on the previous days pasture allocation and fodder beet was grazed in situ in a separate paddock. To improve utilization of FB and ease of measuring refusals, the crop was pulled/harvested from the soil and chopped and lay on top of the soil before feeding. After three hours of offering supplement cows were given access to their pasture allocation and ad lib water from portable troughs.

Allocation of grazing area was based on the amount of DM needed per cow per day to support current milk yield. Covariate milk yield was 1.5 kg MS/cow/day that would require

an average of 15 kg DM/cow/day above a pasture residual of 1500 kg DM/ha (assuming an M/D of 12.0).

4.2.5. FEED MEASUREMENTS

Pasture mass was estimated from compressed height pre and post grazing using rising plate meter (Jenquip) which was calibrated for pasture mass $\text{kg DM/ha} = 140 \times \text{RPM reading} + 500$. Fodder beet yield and utilization was measured every 3 days (same dates as milk sampling day, totaling 6 measurements conducted) as described by Jim Gibbs (2011). Briefly, fodder beet was determined by harvesting all bulbs along two $\times 6\text{m}$ transects. At first weigh bulb with leaf combined. Thereafter, each of the bulb and leaf is separately weighed and recorded. All soil aggregating around the bulb was properly removed by scraping with blade of machete/knife before weighing to ensure that the actual weight of the bulb and leaf is determined. Finally, sub samples (100-200g) of bulb and leaf were extracted and weighed separately before oven drying for dry matter (DM%) determination. To ensure dry matter (DM) determination, the bulb was cut into quarters lengthways from the crown to the base and then one quarter was diced and shredded in a kitchen blender. Shredded samples were then weighed into pre-weighed trays and oven-dried at 65°C in a thin layer until constant weight was achieved at around 48-72 hrs. Sub samples were also freeze-dried for chemical analysis.



Figure 4.2. Showing fodder beet yield cut operations during late lactation experiment.



Figure 4.3. Cows grazing fodder beet during autumn experiment

Sub samples of silage were collected before feeding every sampling day to determine DM % for approximate allocation of DM required. Also, during the 3-day measurement periods, the amount of silage rejected after 24 hours was weighed and sampled for determination of DM content and sub samples were also freeze-dried for chemical analysis.

Herbage samples were collected for DM content and chemical analysis (approx. 1 hr) before and after grazing each sampling day. Herbage was sampled to soil level, and a subsample was weighed, oven dried and reweighed for DM determination. A second sub sample (50 g FW) was sorted to leaf and stem for determination of diet selection. The remaining sampled was freeze-dried, ground and chemical composition analyzed. Chemical analysis for pastures and supplements was performed by near-infrared spectrophotometry (Feed and Forage Analyzer, FOSS Analytical, Hillerod, Denmark)) for Acid Detergent Fibre (ADF), Neutral Detergent Fibre (NDF), crude protein and dry matter digestibility (DMD) determination (Van Soest, 1991), also ground samples of FB were assessed for N: Elementar (Variomax CN Analyser, Elementar Analysensysteme, Germany), ADF, NDF (Van Soest et al. 1991), ash and WSC (Pollock & Jones 1979).

Metabolizable energy content was calculated using the modified ADF (MADF) equation where ME (MJ ME/kg DM) = $14.55 - 0.0155 * MADF$ (CSIRO, 2007). The calibration is based on principal component analysis using a first derivative modified partial least squares mathematical interpretation (Shenk & Westerhaus 1991).

4.2.6. ANIMAL MEASUREMENTS

Group apparent intake of herbage DM (kg DM/cow/d) was determined as the difference between pre and post grazing pasture mass divided by the area and number of animals. Apparent intake of supplement was determined by the difference in fresh weight of the offered and refused supplement multiplied by their respective DM%. The daily combined daily total intake (kg DM/cow/d) on the respective treatments could then be calculated.

Milk yields were recorded daily for each cow throughout the trial including adaptation period using an automatic milk recording system. Milk subsamples were collected for every cow at a.m and p.m milking every 3 days, and analyzed for fat, protein and lactose concentrations by MilkoScan (Foss Electric, Hillerod, Denmark) at Livestock Improvement Corporation Ltd, (Hornby, Christchurch, New Zealand). Milk urea nitrogen was measured for milk samples collected twice (am and pm) during the last week (days 16 and 21) of the trial. The sub samples that were used to determine MUN were centrifuged at 4000 x g for 10 min at room temperature and refrigerated for 10 min to allow the fat to solidify on the top and be

removed. The skim milk was then pipetted into a clean micro-centrifuge tube, chilled, and transported to the laboratory for immediate analysis. Milk urea N was analyzed on an automated Modular P analyzer (Roche Hitachi, Basel, Switzerland) by an enzymatic assay described previously (Talke and Schubert, 1965).

Live weight was recorded daily using a walk over automatic scales as cows left the milking shed. The body condition of cows was scored at the start of the experiment and then last day of the trial by an independent, Dairy NZ registered observer using a ten points scale (1 = thin; 10 = fat) Roche, et al., 2007.

Grazing behaviour (time grazing and time ruminating, mins/day) was recorded in 6 random cows per treatment (i.e. 2 cows per replicate) using CowManager SensOor ear tags is a complete plug and play system that records minutes per hour of each activity (Borchers, et al., 2016). CowManager functions with the aid of SensOor, tagged on the ear for measuring activities such as eating, ruminating, idling etc, data obtained are transferred to a central Router (Solar system). Router(s) (Reception of SensOor data, range 1000m in clear vision), Coordinator (Reception of SensOor data, receives data through Router, connected to PC). The Cowmanager tags were attached to the cows on the 24 April 2017 and after three days for tag adjustment the data used were from 27 April to 8 May 2017.

Dung and urine samples were collected from the drenching/sampling race at the milking shed on the Lincoln University Dairy Research Farm. Spot samples of urine (by gently stroking cow under vulva) and faeces (by rectal grab samples) were collected from each cow following evening and morning milking twice (days 16 and 21). Urine samples were analyzed for total N, creatinine, Urea N and ammonia, and purine derivatives. Faecal samples were analyzed for total N. Urine and fecal N percentages, as well as urine NH_3 , urine urea concentration was determined by using N analyzer (Vario MAX CN, Elementar Analysensysteme, Hanau, Germany). Creatinine concentration of urine was determined by the Jaffe method (Bartels and Bohmer, 1971; Cobas Mira Plus Analyzer, Roche Hitachi, Basel, Switzerland) at the Lincoln University Analytical Services (Lincoln University, Christchurch, New Zealand).

Urine and liveweight data were used to estimate urinary N excretion using the following equation below from Pacheco et al. (2009).

Urinary g of N/d = 21.9 (mg/kg) × BW (kg) × 1/ urinary creatinine (mg/kg) × urine N (g/kg)

4.2.7. STATISTICAL ANALYSIS

Milk, urine and faeces means for each treatment groups were estimated using data from individual measurements from animal samples over sampling days. Intake and herbage measurements were estimated as means for the treatment group as animals grazed together in their treatment groups. The effect of pasture type on milk, urine and faecal measurements was analyzed for variance using GenStat 18.1 (VSN International LTD), with cows as random effect and pasture type as fixed effect using a one-way ANOVA. Herbage measurements were also analysed by one-way ANOVA using Genstat with sampling day as the replicate. All means were separated using Fishers protected LSD test at the 5% significance level

4.3 Results

4.3.1 CLIMATE

The mean maximum temperature was 19°C, and the mean minimum temperature was 14°C (Figure 4.3). The average sunshine was 10 hours, with sunrise at 07:18 AM and sunset at 05:37 PM, moonrise 08:47 AM and moonset at 07:10 PM. There was minimal (94 mm) rainfall over the period (Figure 4.4), (Lincoln historical weather, 2017).

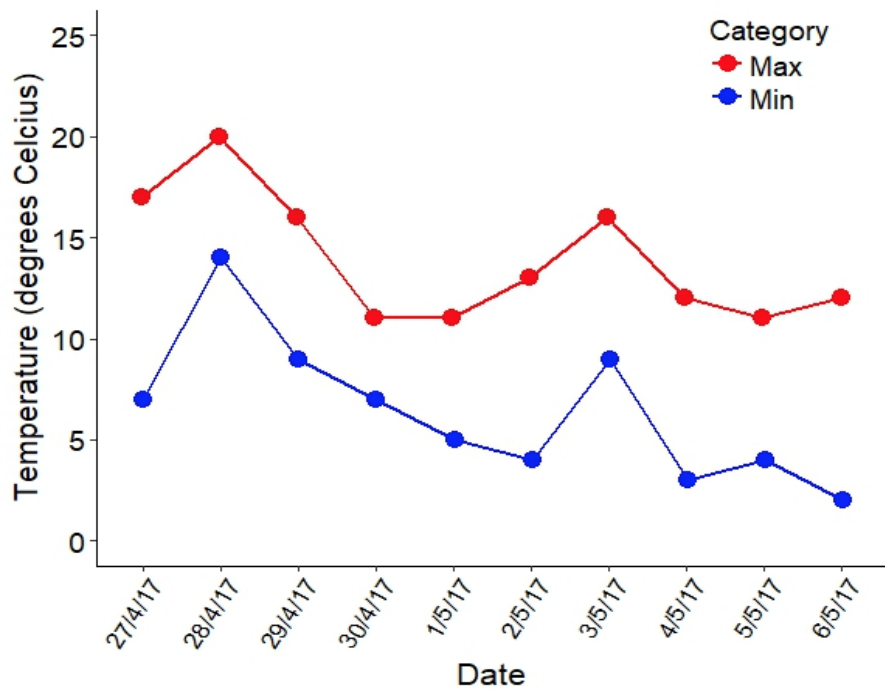


Figure. 4.4 Mean temperature (max) and (min) as recorded during the experiment in autumn.

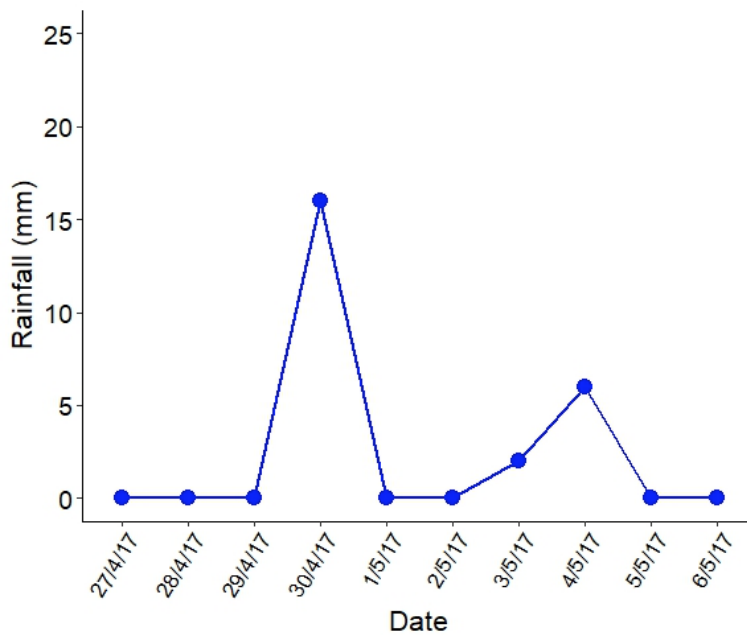


Figure 4.5. Mean rainfall (mm) as recorded during period of the experiment

DIET CHARACTERISTICS

Physical and chemical characteristics of pasture and supplements are presented in Tables 4.1 and 4.2 respectively. Unintentionally, there were differences in pre graze pasture mass between all the treatments, with cows in the OS group receiving pasture with a higher mass compared with other treatments (Table 4.1). There was no difference in post graze pasture mass. In spite of differences in pre graze mass the chemical/nutritional composition of pasture herbage offered to each treatment was similar.

Table 4.1. Chemical composition of pasture offered to cows supplement with fodder beet (FB), oat silage (OS) or ryegrass silage (RGS)

Item	RGS	FB	OS	SEM	P value
Pre-grazing mass (kg DM/ha)	3664 ^a	3544 ^b	3761 ^a	118.1	0.001
Post-grazing mass (kg DM/ha)	1559	1618	1515	48.00	0.114
Crude protein (% of DM)	17.8	17.7	17.9	0.71	0.99
ADF (% of DM)	24.7	25.5	23.8	0.86	0.16
NDF (% of DM)	46.1	47.3	44.3	1.47	0.17
DOMD (% of DM)	76.3	75.5	77.7	1.17	0.23
DMD (% of DM)	79.6	78.8	80.4	0.88	0.25
WSC (% of DM)	18.0	17.0	20.1	1.64	0.15
ME (MJ/kg of DM)	12.2	12.1	12.4	1.05	0.20

ADF = acid detergent fibre; NDF = neutral detergent fibre; DOMD = dry organic matter digestibility; DMD = dry matter digestibility; WSC = water-soluble carbohydrate; ME = metabolizable energy.

The supplement differed markedly in chemical composition (Table 4.2). Fodder beet had the highest values of CP, WSC and ME compared with RGS and OS, there was tendency of significance ($P < .001$) while the OS had the highest NDF and ADF values.

Table 4.2. Nutritional composition of fodder beet (FB), oat silage (OS and ryegrass silage (RGS) offered.

Items	RGS	FB	OS	SEM	P Value
Leaf:stem or bulb	89/11	20/80	17/83	2.66	< .001
Neutral detergent fibre (% DM)	44.2 ^a	18.4 ^b	62.7 ^a	1.4	< .001
Acid detergent fibre (% DM)	28.3 ^b	10.1 ^b	40.2 ^a	0.9	< .001
Crude protein (% DM)	13.1 ^a	14.9 ^a	7.7 ^b	0.7	< .001
Water soluble CHO (% /DM)	8.7 ^b	60.1 ^a	4.6 ^b	0.8	< .001
Metabolisable energy (MJ/ DM)	10.2 ^b	13.0 ^a	8.3 ^b	0.08	< .001

FB = fodder beet; OS = oat silage; RGS = ryegrass silage; DM = dry matter; CHO = carbohydrate; MJ = megajoule

INTAKE AND MILK PRODUCTION

Compared with the control (RGS) supplementing with OS increased pasture intake while supplementing with FB reduced pasture intake (Table 4.3). Although there were differences ($P = 0.05$) in pasture apparent DM intake, these were offset by supplement intake, which tended to be lower for OS, resulting in no effect of treatments on total DM intake (Table 4.3). The low quality (ME) of the OS resulted in lower ME intake and lower milk and milk solid yield compared with RGS or FB supplementation – which had similar milk production. Milk fat (%) was similar ($P = 0.52$) between the 3 treatments group, milk fat (kg) was similar ($P = 0.12$) across treatment groups too (Table 4.3).

Table 4.3. Mean apparent DM intake, milk yield and composition of late lactating cows offered 3 kg DM supplement of ryegrass silage (RGS), fodder beet (FB), or oat silage (OS) or ryegrass silage (RGS) with a pasture- based diet.

Items	RGS	FB	OS	SEM	P Value
Herbage intake (kg DM/cow/d)	11.6 ^b	11.3 ^b	12.0 ^a	0.24	0.05
Supplement intake (kg DM/cow/d)	4.0	3.9	3.8	0.1	0.08
Total intake (kg DM/cow/d)	15.6	15.2	15.7	0.35	0.69
ME intake (MJ ME/cow/d)	182 ^b	189 ^a	178 ^b	0.32	<.001
Milk yield (lt/cow/d)	11.3 ^a	11.0 ^a	9.8 ^b	0.55	0.02
Milk fat (%)	5.76	5.86	5.97	0.23	0.52
Milk fat (kg/cow/d)	0.61	0.64	0.61	0.03	0.12
Milk protein (%)	4.47 ^b	4.78 ^a	4.56 ^b	0.14	0.02
Milk protein (kg/cow/d)	0.50 ^a	0.52 ^a	0.44 ^b	0.28	0.01
Milk Solid (kg/cow/d)	1.11 ^a	1.16 ^a	1.05 ^b	0.06	0.04
Average Liveweight change (kg)	1.1 ^b	3.8 ^a	4.2 ^a	0.39	< 0.01

^{a-c} Means within rows having different superscripts differ significantly ($P < 0.05$).

As this was a late lactation study, the decline in milk yield over time is evident in Figure 4.5 which also shows the similarity between RGS and FB supplementation. Four days into the transition period (18th to 21st April) milk yield diverged for the treatments highlighting the length of adaptation. Moreover, the cows supplement the OS remained consistently lower yielding over the remainder of the experimental period.

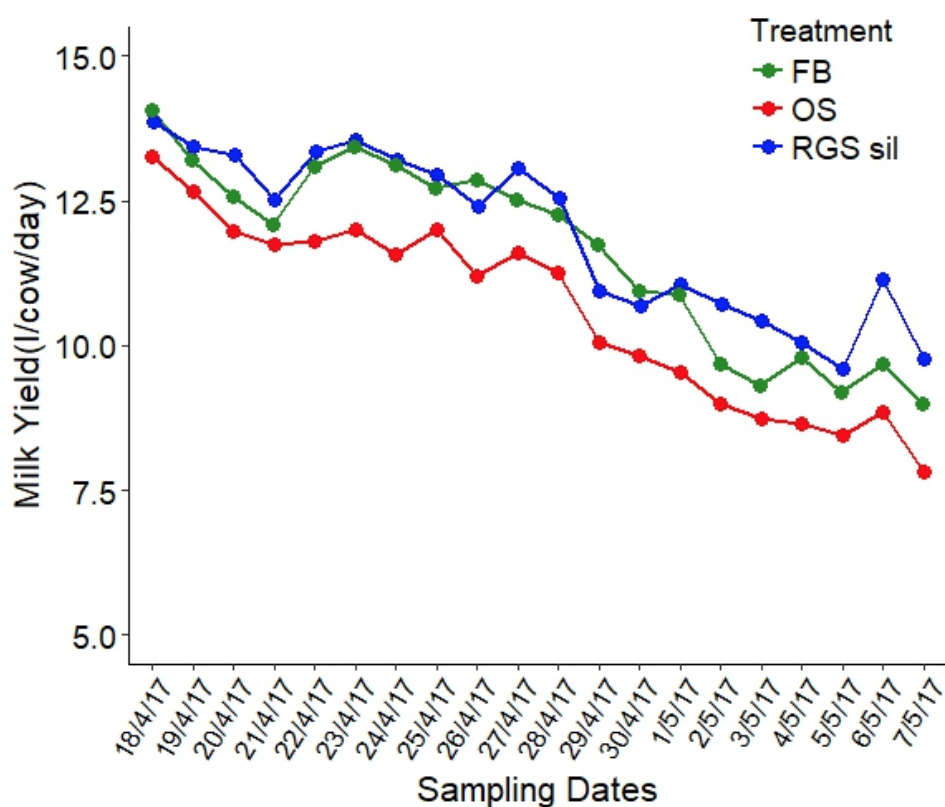


Figure 4.6. Mean daily milk yield of cows supplemented fodder beet (FB), oat silage (OS) and ryegrass silage (RGS) in addition to pasture during late lactation (April-May).

Cows spent 25-26% of their time in grazing activities, which equates to roughly six hours per day. There was no effect of supplementation on time spent grazing ($P = 0.329$). Also, no differences ($P = 0.273$) were observed between time spent ruminating between the three treatments (Table 4.4).

Table 4.4. Mean grazing activities (min/cow/day) of late lactation cows supplemented with ryegrass silage (RGS), fodder beet (FB), or oat silage (OS) or ryegrass silage (RGS) in addition to pasture.

Activity	RGS	FB	OS	SEM	P Value
Ruminating	437	395	410	16.7	0.273
Grazing	369	376	408	17.9	0.329
Idling	634	669	622	14.2	0.370

Eating behavior in this trial (Figure 4.4) shows that the pattern of grazing was the same across the treatment groups. The cows grazed over 50% of their DMI immediately after milking (AM and PM), out of which over 70% was after AM milking. Rumination activities (Figure 4.7b) shows similar pattern across treatment groups.

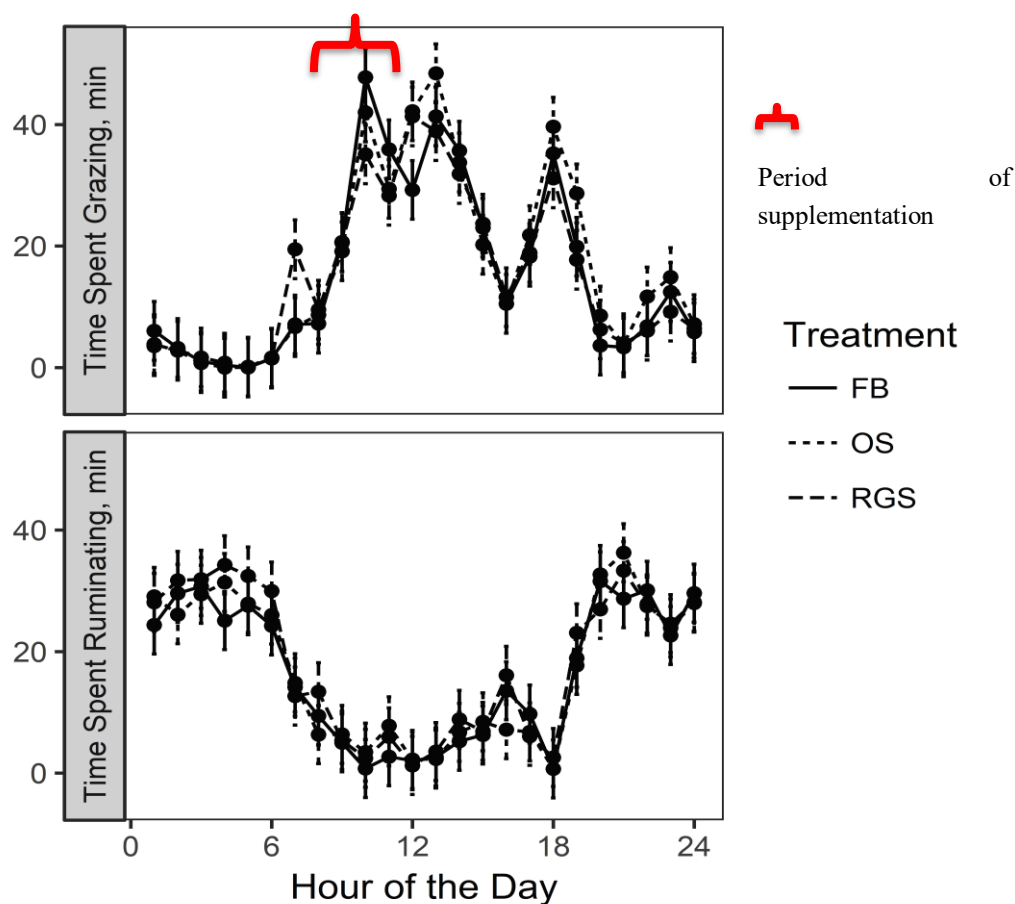


Figure 4.7a and b. Showing mean time spent (min/hr) grazing and rumination of cows supplemented fodder beet, ryegrass silage and/or oat silage in autumn for 24 hours.

NITROGEN UTILIZATION

There was no difference in apparent N intake for cows supplemented with FB compared with the RGS control, though N intake was lower for cows in OS treatment (Table 4.5, $P < 0.05$). The FB treatment had the lowest ($P = 0.004$) MU value while RGS had the highest values of MUN. The cows fed FB had lower ($P < 0.001$) urinary N content (%) compared with those of the cows fed RGS and OS. Estimated urinary N concentration was greatest for RGS and lowest for FB (Table 4.5). Nitrogen in milk concentration was higher ($P < 0.001$) in FB and lower in OS treatment. Cows supplemented with FB had highest ($P < 0.001$) nitrogen use efficiency (NUE), followed by RGS and was lowest in cows fed OS (Table 4.5).

Table 4.5. Mean of apparent N intake, milk urea N, urine N, n in milk and NUE of cows supplemented ryegrass silage (RGS) fodder beet (FB), or oat silage (OS) in autumn.

Items	RGS	FB	OS	SEM	P value
Apparent N intake (g/cow/day)	414 ^a	413 ^a	390 ^b	3.6	< .001
Milk urea (mg/dL)	44 ^a	37 ^b	40 ^a	2.6	0.004
Urine N (%)	0.40 ^a	0.28 ^b	0.39 ^a	0.02	< .001
Urine N concentration (g N/L)	2.35 ^a	1.47 ^b	2.05 ^a	1.32	< .001
PD:creatinine	1.9	2.0	2.1	0.17	0.572
Faecal (N%)	2.8 ^a	2.5 ^b	2.4 ^b	0.08	< .001
N in Milk (g/cow/d)	77.0 ^b	81.5 ^a	68.9 ^c	6.08	< .001
NUE	0.19 ^b	0.21 ^a	0.19 ^b	0.04	< .001

^{a-b} Means within a row with different superscripts differ (P < 0.05). PD= purine derivative; NUE= nitrogen use efficiency

4.4. Discussion

The null hypothesis of this study was that supplement would not affect milk production, milk composition or alter N utilisation. Under the conditions of this study, we were able to reject the null hypothesis on some accounts.

4.4.1. MILK PRODUCTION AND COMPOSITION

In early lactation (Chapter 3) adding FB and OS supplement did not alter milk yield, even when DMI was increased. In the current study the control treatment included supplementing pasture with pasture silage and we found that replacing RGS with OS in late lactation resulted in lower milk yield. Although dry matter intake and ME intake was statistically similar for both treatments, cows offered OS consumed 4 MJ less than those on

RGS as a result of the lower quality of the OS supplement. Lets say 84 MJ ME/cow/day MS is the requirement (DairyNZ, 2017), the 4 MJ, if utilized for milk production, equals to 0.05 kg MS, which is similar to the 0.05 and 0.11 kg MS/cow/day difference between the ryegrass silage and FB treatments respectively. This shows that the low quality (ME) value of the OS supplement affected MS production compared to RGS and FB. Also, the lower milk volume and milk protein concentration in the OS treatment compared to both RGS and FB contributed significantly to the poorer MS production. Similar result was reported by (Fisher et al., 1994), where small increase in milk yield was observed when FB was offered together with various amounts of protein. Previous research has shown that higher levels of WSC, as with FB, have the capacity to produce energy that can enable rumen microbes to capture more N discharged from herbage protein degradation (Kingston-Smith & Theodorou, 2000). In the current experiment, supplementing with FB increased milk protein concentration compared to other supplements. However, numerical variation in milk volume resulted in no difference in milk protein concentration compared with RGS but there was difference in milk protein yield (%) compared with RGS. Previous research have reported increased milk protein yield due to higher energy supplement (Bryant et al., 2013; Rius et al., 2010). These authors regarded the effect of supplements high in fermentable energy as providing more gluconeogenic precursors (propionate) and sparing amino acids.

Milk production response can be related with lower structural fiber content in the diet, because high WSC and low fibre concentration in diets tend to increase organic matter digestibility (OMD) and can lead to a higher digestible DMI, (Miller et al., 2001). In this study, supplements such as OS that had high fibre did not disadvantage intake. It is probable that in late lactation, when energy demands are declining there is less sensitivity to variation in feed quality. Milk yield declined throughout the study (Figure 4.6) and animals spent only 30% of the day grazing. Numerically there were differences in ruminating time whereby treatments with the high fibre supplements OS and RGS spent an additional 15 or 40 minutes per day ruminating compared with cows on FB.

As with early lactation results in Chapter 3, supplementing with FB in late lactation showed no effect on milk yield relative to the control. In Chapter 3 we were able to use a no supplement control to determine substitution rate. Cows offered FB had the highest post

graze pasture residual, even compared to when feeding OS. In this study, the pasture residual was again numerically higher for FB, so it is safe to say that same pattern of high substitution rate observed in early lactation might also be evident in late lactation.

Although there was little scope to increase utilization of pasture on these treatments, it was anticipated that differences in chemical composition of supplements would improve nutrient efficiency for production. In overseas studies, Philips, Sutton and Jones (1995) reported a 12.6% increase in milk volume per cow when grazing dairy cows were supplemented fodder beet. Similarly, Cosgrove et al., (2007) reported minimal rise in milk volume and MS yields when HSG (cv. AberDart) was fed to grazing dairy cows in autumn (late lactation), also a rise of 2.7 kg MS/cow/day (+21%) was reported when high sugar grass was fed to late lactation grazing dairy cows (Miller et al. 2001b).

While increased sugars in the feed can increase propionate in the rumen, equally a high fibre diet can increase acetate and fat percent in the milk, or body condition score gain. We did not see a response to OS with respect to milk fat, even though NDF was high for OS. Ultimately, in this study, the digestibility or ME value of the supplement has been more important in determining milk solids yield than the protein, sugars or fibre. It is therefore safe to say that the ME in OS not reflected in the milk solid production compared to RGS despite no difference is partitioned in live weight gain as shown in Table 4.3. OS cows recorded an average of 2.3 kg/cow/day of weight gain compared to 0.06 and 0.21 kg/cow/day for RGS and FB respectively. Chamberlain and Wilkinson, (1996), also reported a target weight gain of 0.25 kg/cow/day under supplementation in late lactation. Similarly, Holmes and Roche, (2007) reported that supplementing grazing dairy cows with extra feed resulted in energy been partitioned to body condition, that resulted in low milk response under short period of supplementation.

4.4.2. MILK COMPOSITION

This autumn (late lactation) trial results shows that FB treatment produced the highest (numerically) milk fat concentration, milk protein percentage as well as milk protein concentration, resulting in higher milk solids production compared to the OS treatment (Table 4.3). A lower milk solids production of the OS could be attributed to the low milk yield,

low milk fat concentration and lower milk protein parameters (% and concentration). Supplementating forage crop such as FB is expected to prevent depression of milk fat as a result of the buffering effect of forages on the rumen pH. The effect of buffering is a result of enhanced salivation caused by chewing (Anderson et al., 1999). However, this did not happen because the result of this study reported a numerical higher milk fat concentration in the FB cows compared to the RGS and OS. When grass silage was fed to dairy cows, decreased milk fat concentration was reported but no potential reason was offered (Philips, 1988; O' Brien et al., 1996). It is not unexpected that milk protein results of this study shows that FB had the highest milk protein percentage and concentration which is a indication of the high CP content in the FB leaf (Table 4.2).

4.4.3. NITROGEN UTILIZATION

Reducing urinary N deposition in autumn is an important consideration for farmers. Excess urine N is excreted onto the soil where it is rapidly converted to nitrate and at risk of leaching during the subsequent winter drainage period (Monaghan et al., 2007). Common N intakes in grazing systems in autumn is easily leached from below the root zone compare to urine load in spring and early summer (Snow et al., 2011), therefore, most research focus on these periods to reduce or mitigate urinary N excretion. N intake is the first factor that influences the quantity of N relative to animal need and it shows that there is a direct link between N intake and UN excretion (Van Vuuren et al., 1997). In this study, as expected N intake result shows that there was significant difference between OS and RGS. The high (414 g/cow/day) N intake in RGS diet is expected because of the high CP concentration present in the high quality pasture (ryegrass and clover mixture) which is assumed to be in excess of 200 g/kg DM compared to the low quality (< 10%) CP concentration in OS diet.

A relatively low nitrogen use efficiency (NUE) is typically noticed in dairy cows on pasture due to the high CP of perennial ryegrass and clover during early and late lactation (Juan and Rene, 2011). The results of this study showed that supplementing pasture with low N crop FB improved N utilization by 10.5% compared to RGS and OS respectively (Table 4.5). The indicators for low N loss were evident from low MUN and low urinary concentrations in the FB treatment. Typically improved NUE arises where cows are offered low protein diets (Van

Vuuren et al., 1993; Berzaghi et al., 1996; Carruthers and Neil, 1997; Bargo et al., 2002). Though it would appear that more of the consumed N was partitioned to milk, with perhaps more stable rumen ammonia concentrations as suggested by lower MUN and urine N concentration. Stergiadis et al., (2015) reported increased N utilization, reduced N outputs and low N concentration in urine when pasture lower in N content and higher in fermentable energy was fed to dry cows. The high soluble carbohydrate and low CP in FB bulb provides an important opportunity to reduce UN concentration.

In this study, the average urinary N concentrations ranged between 1.4 (FB) to 2.4 g N/L (RGS) and were lower than the average value of between 4.5-5.4 g N/L and ranges of 6.0-8.6 g N/L reported by Waghorn et al., (2018, 2019) respectively, also lower than the values observed by Dalley et al., (2019) with an average urinary concentration range of 2.5 (FB40) to 3.6 g N/L (Maize). The urinary N concentrations reported in this study were determined from spot samples (afternoon and morning) collected twice in the last seven days of the experiment in contrast to the 24 hr urine collection reported by (Waghorn et al., 2018, 2019).

The large reduction in spot urinary N concentration and trend for increased milk protein on the FB diet despite having high (413 g/cow/day) N intake may be attributed to the ratio of WSC and CP % (Totty et al., 2013). The higher WSC content of the FB supplement may have increased the supply of fermentable energy and protein to meet microbial requirements. As a WSC:CP ratio of greater than 0.7 can decrease the percentage of N intake and subsequently urinary excretion (Edwards et al., 2007a). This experiment recorded a WSC:CP ratio of 4.03 in the FB treatment compared to 0.59 and 0.66 respectively in the OS and RGS treatments.

4.5. Conclusions

The results obtained in this experiment shows that dairy cows on pasture supplemented with low CP, and high energy diets such as FB can be used to replace conventional ryegrass silages to maintain milk production as well as reduce/mitigate urine N loading in autumn. Low quality oats silages may be better used for meeting maintenance requirements such as those for non-lactating cows during winter as a protein and fibre supplement for FB.

Chapter 5

Effect of supplementing oat forage or fodder beet on milk production, milk quality and N utilization of cows in early lactation

5.1. Introduction

Previous research has shown that feeding low N crops such as fodder beet reduces N intake and subsequently UN excretion (Chakwizira et al, 2016. Edwards et., al.2014). Because of economic feasibility farmer adoption of fodder beet (FB) as a winter crop has been rapid. However, with little science to support the concept, farmers have started feeding FB in early lactation to manage rumen transition from one diet to another (off FB onto pasture). However, in spring the low N content of FB could limit milk production at a time when cows have increased demand for protein. This supposition was put forward as an explanation for lack of milk response to FB supplementation in the first experiment (Chapter 3).

Because of the high yields of FB and resulting high stocking density on these feeds, catch crop oats are recommended to be sown after FB to capture soil nitrate. However, there are concerns about the practical logistics of sowing a catch crop when the ground is still wet. During a long wet winter, oat establishment may be late, delaying crop maturity to later in spring. It is not clear what impact a later sowing date will have on reducing N leaching or on management of oats or animal production if the intention is to feed oats as a standing crop. There is the question of how to manage the oats catch crop, as the rapid growth of this crop can create an unplanned feed surplus and farmers are uncertain whether to graze or ensile oats in spring. Increasing DM allocation during a feed surplus may increase voluntary feed intake, or reduce pasture utilization, or both.

In chapter 3 no clear benefit to milk production, milk composition was found by using winter crops as supplements in early lactation. This may have been due to the high quality of the pasture and the high substitution rates resulting in no net benefit with regards to milk yield. In that study (Chapter 3), a dry winter enabled early sowing of oat, which did not result in a feed with better quality than pasture on offer at the time of experimentation. The question arises whether late sown oats might mature in time for grazing to offer energy and protein when ryegrass pasture is declining in quality.

In commercial practice consideration needs to be given to management of these feeds and how they may affect pasture management, animal productivity and product quality. It is expected that including new forages into the diet will impact the quality of the milk, and often this has been observed with fatty acid profiles (Daley et al., 2010). For example conjugated linoleic acid (CLA) is an aspect of milk fat that might be advantageous to human health due to anticarcinogenic characteristics (Melendez et al., 2016) and diet manipulation could seek to boost the quantity of CLA in dairy products. Therefore, this experiment was again aimed at investigating the effect of feeding fodder beet bulb versus late sown oat forage to grazing cows in early lactation to assess repeatability of the milk response and identify whether changes in grazing behavior can explain substitution effects. Moreover, the results will look more closely at the impact of forages on milk quality.

5.1.1. HYPOTHESIS

This study tested the hypothesis that supplementing winter crops to dairy cows in early lactation will improve milk production and milk quality while reducing environmental impacts.

5.2. Materials and methods

5.2.1. EXPERIMENTAL SITE AND DESIGN

The experiment was carried out between 16th November and 7th December 2017 at the Lincoln University Research Dairy Farm (43°38'S, 172°27'E) with the approval of the Lincoln University Animal Ethic Committee (AEC Appln2017-37). The soil type was a Templeton sandy loam. The experiment was a completely randomized design with three supplement treatments and three replicates. All treatments consisted of base herbage of perennial ryegrass and white clover pasture offered at 18 kg DM/cow/day above 3.5 cm compressed height. Supplement treatments were no supplement (CON), versus oat forage (OF), or fodder beet (FB), which were offered at 3 kg DM/cow/day.

The experimental area consisted of 11 ha of mixed age permanent pastures of perennial ryegrass/white clover (*Lolium perenne*/*Trifolium repens*). All experimental paddocks were fertilized with urea (46 %N) at a rate of 50 kg N/ha in late October, 2017. Pasture mass was monitored pre and post grazing using a rising plate meter (Jenquip) which measured compressed height. The manufacturers equation for leafy pastures was used to calculate pasture mass from height using the following equation: kg DM/ha = 140 x RPM reading + 500.

The oat forage supplement was grown on 0.5ha near the experimental pasture. Following cultivation, oat seed (cv. Milton) was drilled on 8 September 2017, at 100kg/ha and 50 kg N fertilizer was applied at emergence. In practice oats would follow the FB crop at the end of winter-feeding period, however, for the purpose of this study the FB was grown off-farm at Ashley Dene Research and Development Station (ADRDS) (43° 65⁰N, 172°33⁰E). The fodder beet (FB) bulb was lifted on the 17 September 2017 and stored in windrows 2.5m high and 6m wide.

5.2.2. ANIMALS AND MANAGEMENT

Cows for the experiment were selected from a larger group of animals. A covariate milk yield period was used to generate the sample population two weeks prior to the experiment. A total of 36 high-producing Friesian × Jersey crossbred multiparous cows were allocated into replicated ($n=3$) groups for each of the three treatments, balanced for age (5.5 ± 3 years), milk solids production (2.53 ± 0.5 kg MS/cow/day), days in milk (66 ± 2 days) and live weight (509 ± 14 kg LW). During the experiment pasture allocation for all treatments was isoenergetic (220 MJ ME/cow/day) being dictated by the energy requirements to meet covariate milk yield and maintenance requirements. Prior to the experiment, diets consisted solely of ryegrass and white clover pasture, requiring a seven days adaptation period of increasing supplement by 0.5 kg DM every two days. Milk yield was measured between the 23rd November and 7th December

To ascertain if voluntary intake could be increased by supplementation during a feed surplus period, DM allocation was increased by an additional 15-18% (3 kg DM/cow/day) as supplement compared with CON. Each day the supplemented groups (FB and OF) were allocated their supplement at 0900 hr and after two hours were moved to their pasture allocation at 1100 h. The CON group was offered a new pasture allocation at 0900 hr. The target pre and post grazing herbage mass was 2800-3000 kg DM/ha and 1500 kg DM/ha allowing for target intake of 18 kg DM/cow/day (approximately 130 m²/cow/d).

All pasture allocations were back-fenced and cows had ad lib access to clean fresh water. Cows in the OF group were shifted to the oats paddock daily where they grazed in situ. To ensure similar walking distance for supplement treatments the FB group received their supplement in trough in a separate paddock devoid of pasture. Both the OF and FB groups were moved between supplement and pasture each morning whereas CON moved only between pasture and milking parlor. Allocation area of forage oats was based on available forage mass above 6 cm. The OF was offered as a standing crop behind temporary electric fencing, whereas the FB was chopped with machete and fed to cows in a plastic trough for ease of determining utilization. Each

day supplement intake was determined by weighing offered and refused (FB) or harvesting samples of pre and post graze mass (OF).

5.2.3. PASTURE AND SUPPLEMENT MEASUREMENTS

Pasture herbage samples were collected for DM content and chemical analysis before and after grazing (approx. 1 hr) each sampling day. Herbage was sampled to soil level, and a subsample was weighed, oven dried and reweighed for DM determination. A second sub sample (50 g FW) was sorted to leaf and stem for determination of diet selection. The remaining sample was freeze-dried, ground and chemical composition analyzed. Chemical analysis for pastures and supplements was performed by near-infrared spectrophotometry (Feed and Forage Analyzer, FOSS Analytical, Hillerød, Denmark) for ADF, NDF, crude protein and dry matter digestibility (DMD) determination (Van Soest, 1991), also NIRS analysis was supported by wet chemistry analysis of samples (AOAC, 1990). Metabolizable energy content was calculated using the modified ADF (MADF) equation where ME (MJ ME/kg DM) = $14.55 - 0.155 * \text{MADF}$ (CSIRO, 2007). Wet chemistry (FB) analyses were entered into the NIRS database, the calibration is based on principal component analysis using a first derivative modified partial least squares mathematical interpretation (Shenk & Westerhaus 1991)

Sub samples of supplement were collected each sampling day (every 3 days), dried in a microwave oven to provide an approximate measure of DM content. These values were used to calculate how much fresh weight of each supplement was required to supply 3 kg DM/cow/d. Sub samples were also collected each sampling date and freeze dried for near infrared spectrophotometry (NIRS) to determine the chemical composition of herbage and supplements.

During each measurement period amounts of supplement refusals after 24 hours was weighed and sampled for determination of DM content. The daily supplement DM intake (kg DM/cow/d) on the supplemented treatments was then calculated. Oat forage yield cuts were carried out twice every week prior to and during the trial by the use of 0.5m² with 2 cuts at 6m apart, and sub sample oven dried at 65⁰ for 24 hours to determine DM % and subsequent yield DM/ha.

Group apparent intake (kg DM/cow/d) was determined as the difference between pre and post grazing pasture mass divided by the area and number of animals.

Apparent N intake was determined by;

Pasture N (g) × Total Pasture Kg DM intake + Supplement N% × Total Supplement Kg DM intake

Nitrogen use efficiency (NUE) for milk was calculated as:

N in milk (Milk protein g/6.38)/ by apparent N intake

Substitution rate was calculated as: SR (kg/DM) = (pasture DMI in unsupplemented treatment – pasture DMI in supplemented treatment)/supplement DMI.

5.2.4. ANIMAL MEASUREMENTS

Grazing behavior (time grazing and time ruminating, mins/day) was recorded in 6 random cows per treatment (i.e 2 cows per replicate) using CowManager SensOor™ ear tags (Borchers et al., 2016). The CowManager SensOor eartag was attached to the cow's ear on 23 November 2017 (day 7) of the trial immediately after morning milking. Grazing behavior data was collected after transition between 28 November and 5th December).

Live weight and body condition score (BCS) were measured at the beginning of the trial (baseline data) and at the end of the trial, following the a.m milking: live weight were measured using the automatic scale while BCS was assessed on a 10 point scale, where 1 is emaciated and 10 is obese (Roche et al., 2004).

Individual milk yield was recorded daily using an automatic milk recording system (DeLaval Alpro herd management system, DeLaval, Tumba, Sweden). Two milk sub samples were collected for all cows every 3 days at a.m and p.m milking and analyzed for fat, protein and lactose concentrations (Livestock Improvement Corporation, Hornby). Milk urea N was measured for milk samples collected during the last week of the trial, the sub samples were skimmed after centrifuging at 4500g for 10 min at 4°C and the skim milk analyzed by automated Modular P analyzer (Roche Hitachi,

Basel, Switzerland) by an enzymatic assay as described by Talke and Schubert, (1965). Milk N content was calculated from Livestock Improvement Corporation determination of N assuming $\text{milk N (g/kg)} = \text{milk protein (g/kg)} \times 6.38$.

Milk composition parameters (milk fatty acid, vitamins and mineral concentrations) were determined by a commercial milk processing company on bulk milk samples collected from individual cows in each treatment (i.e. pooled replicates) at each sampling date.

Blood, urine and dung samples were collected twice in the final week of the study from spot samples following am and pm sampling (procedure described by Totty et al, 2013). Spot samples of blood were collected from (coccygeal venipuncture) using 10 mL of sodium heparin and K; EDTA vacuette tubes (Greiner Bio-one, Kremsmünster, Austria). Blood samples were placed on ice, and then centrifuged at 3,000 $\times g$ at 4°C for 15 min. and the separated plasma was stored at -20°C until analysis for NEFA, BUN, urea and β HBA. Urine (by manual stimulation of the vulva) and faeces (by grab samples) were collected from each cow following evening and morning milking on days (16 and 21) in the last seven days of trial.

Blood was analyzed for Non-esterified fatty acid (NEFA), blood urea nitrogen (BUN), urea and beta hydroxyl butyrate acetate (β HBA), urine was analyzed for total N, urea-N and ammonia and faecal samples was analyzed for total N by combustion method.

Urine samples were analyzed for total N, creatinine, Urea N and ammonia, and purine derivatives. Faecal samples were analyzed for total N. Urine and fecal N percentages, as well as urine NH_3 , urine urea concentration was determined by using N analyzer (Vario MAX CN, Elementar Analysensysteme, Hanau, Germany). Creatinine concentration of urine was determined by the Jaffe method (Bartels and Bohmer, 1971; Cobas Mira Plus Analyzer, Roche Hitachi, Basel, Switzerland) at the Lincoln University Analytical Services (Lincoln University, Christchurch, New Zealand).

Urine measurements were used to estimate urinary N excretion using the following equation from Pacheco et al. (2009).

N in urine, g/d = ((21.9 x LW, kg)/urinary creatinine, mg/kg) x urine N, g/kg).

5.2.5. STATISTICAL ANALYSIS

Animal milk production variables were averaged across animals in the same group/treatment over four sampling days and analyzed using the general linear model procedure of Genstat (18th Edition; VSN international Ltd) where feeding regime was the fixed term with replicate/group as the random term. Herbage, milk, blood, urine and fecal variables were compared by ANOVA using feeding regime as the fixed term and sampling day as the random term in the general linear model. Milk fatty acid concentration, vitamins and minerals, bulk milk samples (combined milk for three reps) for each treatment, were analyzed for variance using sampling days as the replicate. All means were tested using Fishers protected LSD test at the 5% significance level.

5.2.6. RESULTS

METEOROLOGICAL DATA

Mean monthly temperature and rainfall data were collected from Lincoln historical weather. The mean maximum temperature was 25°C, and the mean minimum temperature was 14°C. The average bright sunshine were 14 hours, with sunrise at 04:43 AM and sunset at 07:59 PM, moonrise 09:29 PM and moonset at 06:08 AM. An accumulated rainfall of <10 mm occurred between 24 November and 3 December, 2017, mean humidity of 72% and mean wind speed of 11 km/h (Lincoln historical weather, 2017).

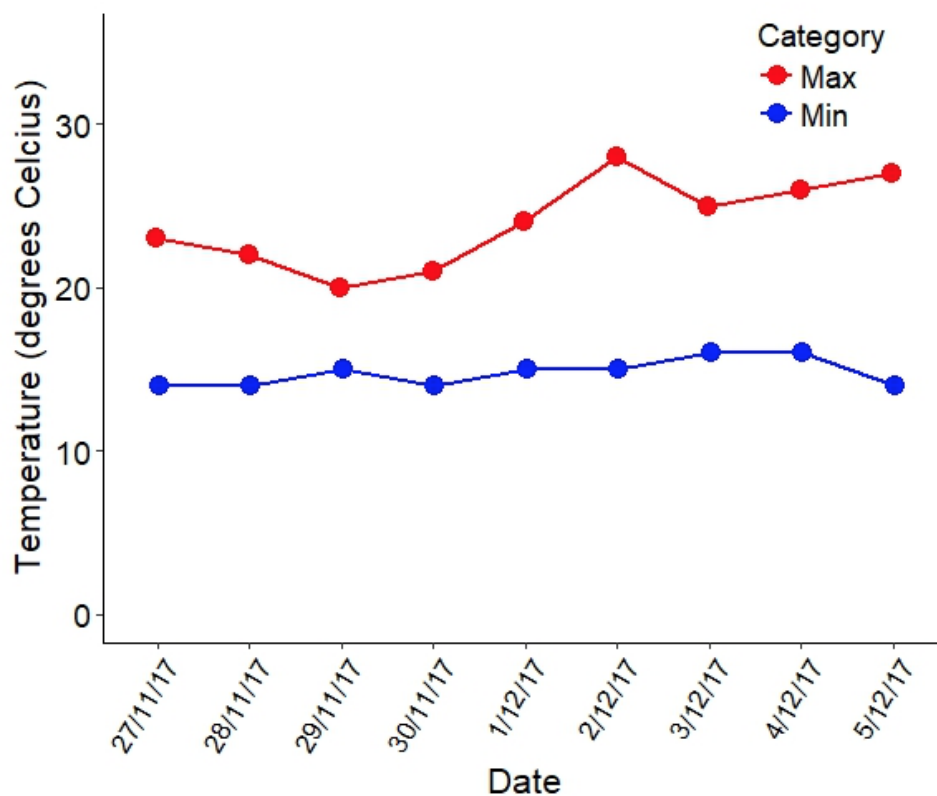


Figure 5.1. Mean climate readings as recorded during the experiment.

DIET CHARACTERISTICS

Physical and chemical characteristics of pasture are presented in Table 1. There was no difference in pre graze pasture mass ($P = 0.11$). However, feeding either FB or OF resulted in higher post graze pasture mass compared with the control ($P < 0.001$, Table 5.1). Herbage utilization was higher ($P < 0.001$) on CON (89%), followed by OF (72%) while FB (65%) had the lowest herbage utilization (Table 5.1).

There was no difference in quality parameters of pasture between treatment groups. No differences were observed between the ADF, similarly no difference was observed between the NDF contents of the pasture (Table 5.1).

Table 5.1. Chemical and botanical composition of base pasture diet offered, percentage utilization of pre-grazing dry matter intake (DMI) of CON, FB and OF treatments offered 18 kg DM/cow/day in late spring.

Item	RG	FB	OF	SEM	P value
Pre-grazing mass (kg DM/ha)	3064	2948	3015	174	0.111
Post-grazing mass (kg DM/ha)	1676 ^b	2026 ^a	1999 ^a	37.0	<0.001
Herbage utilization (%)	89 ^a	65 ^b	72 ^b	22.3	<0.001
Dry matter (%)	22.1	22.3	21.1	1.54	0.142
Clover (%)	9.2	9.7	9.4	0.05	0.936
Dead material (%)	6.5	5.6	6.2	0.03	0.279
Weed (%)	8.2	8.7	9.1	0.09	0.503
Crude protein (%)	16.9	17.1	16.4	0.99	0.809
ADF (%)	28.4	26.7	27.2	0.84	0.143
NDF (%)	49.6	47.9	48.5	1.65	0.564
DOMD (%)	71.6	74.4	73.5	1.59	0.203
DMD (%)	72.7	75.4	74.3	1.29	0.130
WSC (%)	25.0	27.4	27.1	1.50	0.240
ME (MJ/kg/DM)	10.2	10.4	10.3	1.12	0.263

^{a-b} Means within rows having different superscripts differ significantly ($P < 0.05$).

ADF = acid detergent fibre; NDF = neutral detergent fibre; DOMD = dry organic matter digestibility; DMD = dry matter digestibility; WSC = water-soluble carbohydrate; ME = metabolizable energy. Mean within rows with different superscripts are different at ($P < 0.05$) according to SEM.

The composition of the supplements are presented in Table 5.2. The OF forage had a higher ($P < 0.001$) CP content compared with the FB diet. However, the FB forage had a higher ($P < 0.001$) WSC concentration compared with OF, also the FB diet had a higher ($P < 0.001$) ME content compared with OF (Table 5.2). The OF forage had a higher ($P < 0.05$) NDF and ADF ($P < 0.001$) concentration compared with FB (Table 5.2). More so, the ME of OF was similar to the pasture while ME of FB is better than pasture.

Table 5.2. Chemical composition of supplements offered, percentage utilization of supplement dry matter intake (DMI) for FB and OF) offered 3 kg DM/cow/day in late spring

Item	FB	OF	SEM	P value
Forage pre mass (kg DM/ha)	NA	4224	119	Nil
Forage post mass (kg DM/ha)	NA	1787	326	Nil
Dry matter %	21.3	22.2	0.63	0.09
Organic matter %	96.6	92.9	0.27	0.14
Crude protein (%) kg/DM	5.1 ^b	11.9 ^a	0.99	<.001
ADF (%) kg/DM	6.2 ^b	29.4 ^a	1.84	<.001
NDF (%) kg/DM	13.0 ^b	57.0 ^a	3.99	<.001
WSC (%) kg/DM	61.3 ^a	21.7 ^b	1.85	<.001
DOMD	75.9 ^a	64.9 ^b	1.98	<.001
ME (MJ/kg/DM)	13.6 ^a	9.9 ^b	0.29	<.001

^{a-b} Means within rows having different superscripts differ significantly ($P < 0.05$). ADF = acid detergent fibre; NDF = neutral detergent fibre; DOMD = dry organic matter digestibility; DMD = dry matter digestibility; WSC = water-soluble carbohydrate; ME = metabolizable energy; NA = not available.

INTAKE AND MILK PRODUCTION

Time spent eating was variable between cows and days and in spite of large numerical differences in grazing time there were no statistical differences in time spent eating or ruminating (Table 5.3). Cows on pasture only spent approximately six and half hours per day grazing while cows on Oats and FB were respectively roughly seven and eight hours eating. Those on pasture only and OF had more idle time compared with cows on FB.

Table 5.3: Mean effect of forage and catch crop supplementation on time spent eating, ruminating and idling (in minutes) over 24 hrs.

Items	CON	FB	OF	SEM	Pvalue
Eating (min/day)	364	489	385	38.5	0.12
Ruminating (min/day)	525	507	541	20.1	0.53
Idling (min/day)	551 ^a	444 ^b	514 ^a	27.2	0.05

CON = control; FB = fodder beet; OF = oat forage.

The most intense grazing bouts occurred after the morning milking when cows received their allocation of pasture or supplement (Figure 5.2). Those in FB and OF consumed their supplements between 0900 and 1100 h before being transferred to new grass. There were few obvious differences in grazing and ruminating behavior during the supplementation period. Interestingly, the cows offered fodder beet had increased grazing intensity on pasture between 1700 and 2000 h (Figure 5.2). On time spent on supplement between (0900-1100 hrs), FB treatment spent 46 minutes per hour grazing while the OF treatment spent 38 minutes per hour grazing. Rumination activities (Figure 5.1) show a similar pattern across treatment groups. The cows

ruminated between dusk to dawn, with rumination peak of over 40 mins/hr at dusk but prolong rumination was seen at dawn.

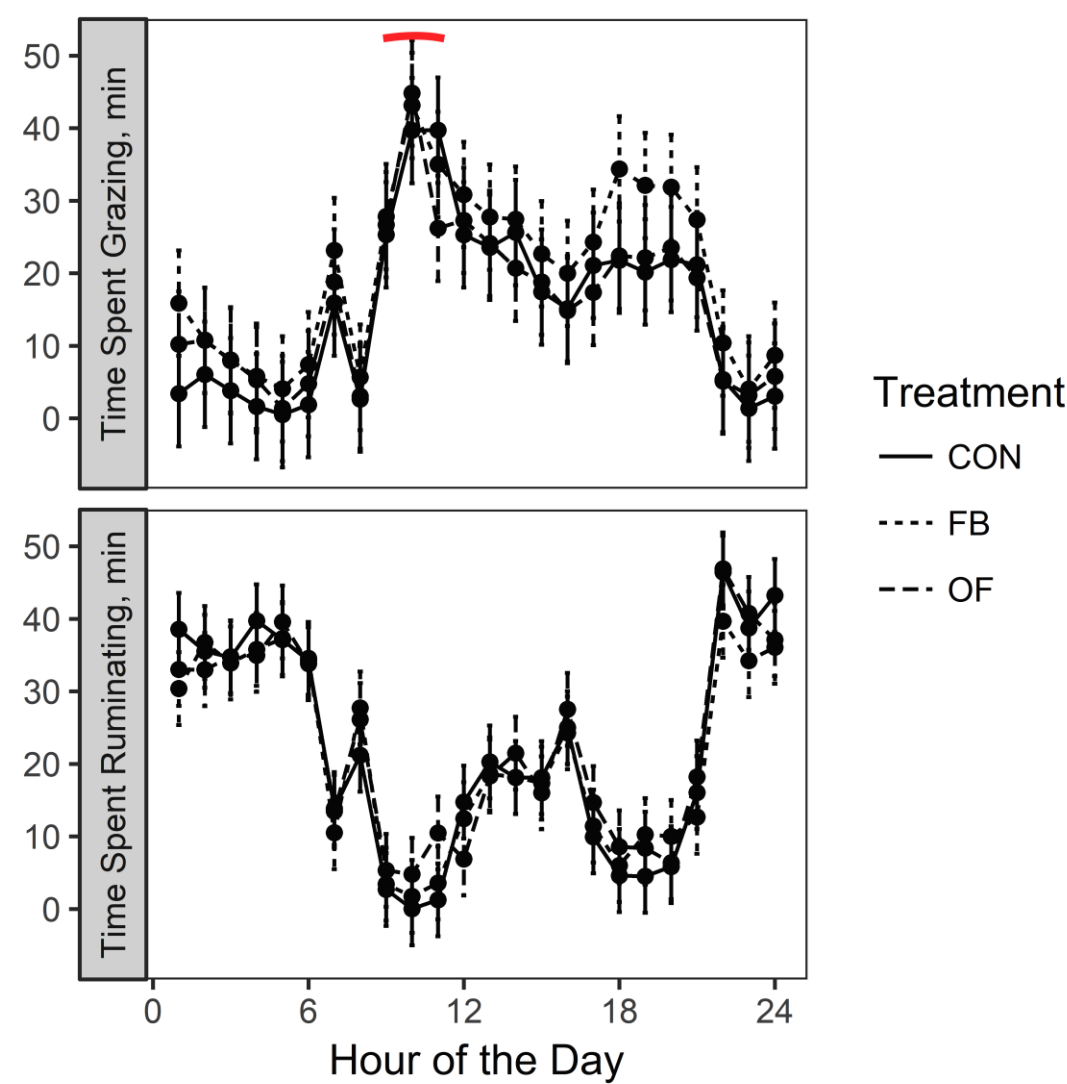


Figure 5.1 & 2 Effect of herbage and supplementation on pattern of grazing and rumination in cows for 24 hrs. The red line is the approximate time the cows were on FB, oats or pasture.

Feeding supplement reduced pasture intake compared to the CON group (Table 5.4). Cows in the OF group tended to consume more supplement than those in the FB group

($P = 0.065$) largely because the OF group were able to exceed their target utilization by grazing lower than 6 cm. However, there was difference ($P = 0.019$) in total apparent DMI between the 3 treatment groups (Table 5.4).

There was a difference in the substitution rate (SR). Cows on FB diet decreased pasture intake by 4.4 kg DM/cow/d resulting in a SR of 1.5. On the other hand cows grazing OF reduced pasture intake by 3.2 kg DM/cow/d resulting in SR of 0.8 (Table 5.4).

Milk yield declined when cows were supplemented with FB ($P = 0.004$; Table 5.4) though changes in milk composition resulted in similar milk solids production for all treatments.

Table 5.4. Mean apparent DM intake, supplement utilization, substitution rate, milk yield and composition of late spring lactating cows offered supplement of fodder beet (FB), or oat forage (OF) with pasture- based diet

Items	CON	FB	OF	SEM	P Value
Herbage intake (kg DM/cow/d)	16.1 ^a	11.7 ^b	12.9 ^b	0.52	<0.001
Supplement intake (kg DM/cow/d)	-	3.0	4.1	0.20	0.065
Supplement utilization (%)	-	100 ^b	137 ^a	26.4	<0.001
Total intake (kg DM/cow/d)	16.1 ^a	14.7 ^b	17.0 ^a	1.35	0.019
Substitution rate (SubR kg)	-	1.5 ^a	0.8 ^b	0.21	<0.001
ME intake (MJ ME/cow/d)	164 ^b	161 ^b	173 ^a	0.32	<.001
Milk yield (lt/cow/d)	22.8 ^a	20.9 ^b	21.9 ^a	0.39	0.004
Milk lactose (kg/cow/day)	1.10	1.05	1.10	0.03	0.255
Milk fat (kg/cow/d)	1.10	1.20	1.10	0.03	0.459
Milk protein (kg/cow/d)	0.82	0.69	0.81	0.10	0.075
Milk solids (kg/cow/d)	1.92	1.89	1.91	0.05	0.814
Live weight change (kg/day)	-0.14	0.19	0.21	14.8	0.309

^{a-c} Means within rows having different superscripts differ significantly ($P < 0.05$).

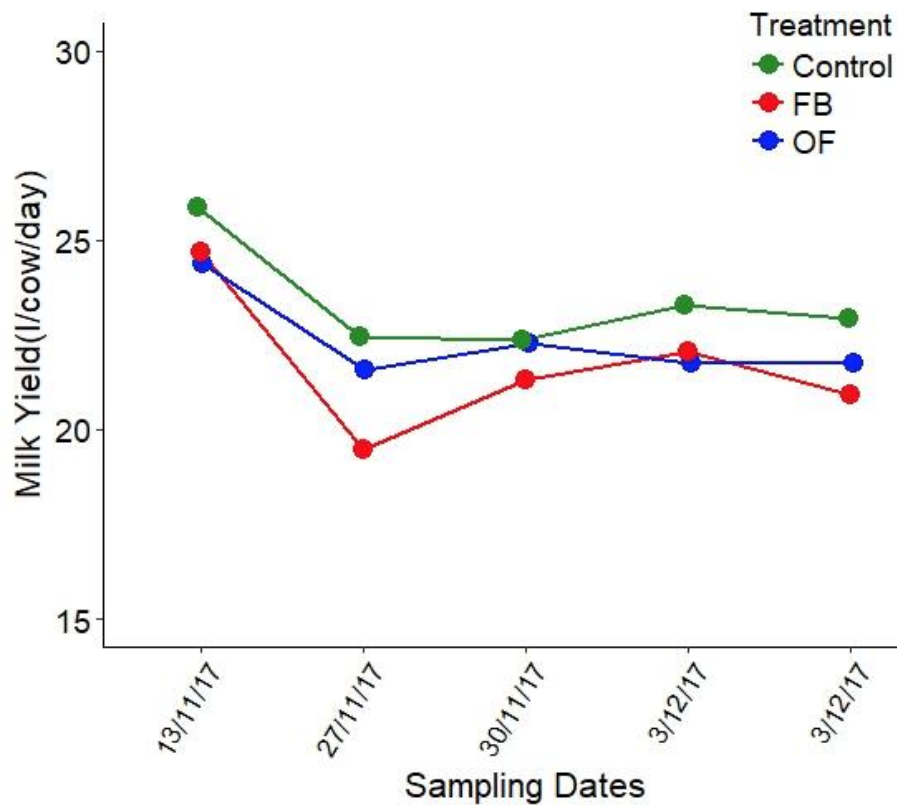


Figure 5.3. Mean of milk yield (l/cow/day) of cows grazing pasture and supplemented with fodder beet (FB), oats forage grazed in situ (oats) or no supplement (CON).

Milk composition

Compared with pasture only (CON) supplementing with FB increased lactose, casein, calcium and fat% (Table 5.5). On the other hand, supplementing with OF decreased mineral potassium compared with CON. The relative difference in milk fat percentage is depicted in Figure 5.4.

Table 5.5. Change in vitamin and mineral composition of milk from cows grazing pasture only (CON) or supplemented with fodder beet or oat forage in late spring

Items	Control	Fodder Beet	Oat Forage	SEM	P val
Lactose (%)	4.5 ^b	5.0 ^a	4.7 ^b	0.11	0.016
Protein (%)	3.6	3.8	3.7	0.05	0.130
Casein (%)	2.88 ^b	2.96 ^a	2.99 ^a	0.02	0.006
Fat (%)	4.2 ^b	4.8 ^a	4.5 ^b	0.13	0.002
Ca (mg/L)	1210 ^b	1348 ^a	1250 ^b	13.9	<0.001
P (mg/L)	984	987	1015	11.9	0.17
K (mg/L)	1602 ^a	1603 ^a	1533 ^b	13.0	0.002
Iodine (mg/L)	0.15	0.15	0.12	0.037	0.74

^{a-b} Means within rows having different superscripts differ significantly ($P < 0.05$).

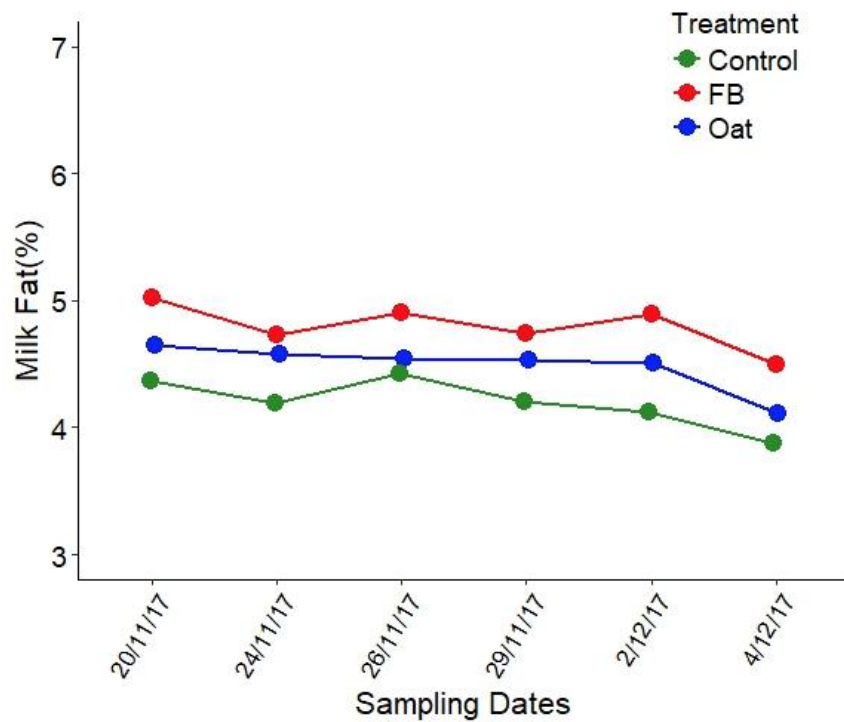


Figure 5.4. Mean of milk fat (%) of cows grazing pasture and supplemented with fodder beet (FB), oats forage grazed in situ (oats) or no supplement (CON)

The fatty acid results showed the cows fed FB had higher concentrations of short chain FA's: C4:0, C6:0, C8:0, C10:0 and C10:1 compared to CON and OF treatments. However, supplementing with FB reduced iso C14, C15:0, iso C16, C18:0 and CLA values compared to CON and OF treatments (Table 5.6).

Table 5.6. Change in milk fatty acid (%) composition of cows in pasture supplemented fodder beet or oat forage in late spring.

Items	Control	Fodder Beet	Oat Forage	SEM	Pvalue
C4:0	3.82 ^a	3.85 ^a	3.53 ^b	0.01	<.001
C6:0	2.41 ^{ab}	2.56 ^a	2.36 ^b	0.00	<.001
C8:0	1.49 ^b	1.65 ^a	1.51 ^{ab}	0.02	<.001
C10:0	3.50 ^b	4.06 ^a	3.74 ^{ab}	0.10	0.001
C10:1	0.34 ^a	0.35 ^a	0.32 ^{ab}	0.01	0.011
C12:0	4.08 ^b	4.74 ^a	4.39 ^{ab}	0.12	0.008
iso C14	0.10 ^a	0.08 ^{ab}	0.11 ^a	0.00	<.001
C14:0	12.3	12.7	12.6	0.14	0.074
iso C15	0.30 ^a	0.25 ^b	0.31 ^a	0.00	<.001
C14:1 anteiso C15	1.63 ^a	1.47 ^b	1.59 ^{ab}	0.02	<.001
C15:0	1.30 ^a	1.21 ^b	1.30 ^a	0.00	0.022
iso C16	0.24 ^a	0.19 ^b	0.24 ^a	0.01	<.001
C16:0	30.6	31.6	30.0	0.62	0.166
C16:1	1.48 ^a	1.52 ^a	1.32 ^b	0.02	<.001
anteiso C17	0.55 ^a	0.49 ^b	0.53 ^a	0.01	0.002
C17:0	0.62	0.59	0.60	0.01	0.078

Table 5.6 continues on next page
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Continuation of Table 5.6

Items	Control	Fodder Beet	Oat Forage	SEM	Pvalue
C17:1	0.27	0.26	0.23	0.01	0.006
C18:0	8.70 ^b	8.69 ^b	9.57 ^a	0.23	0.012
C18:1 t9	0.11 ^a	0.10 ^{ab}	0.11 ^a	0.00	<.001
C18:1 t10	0.00	0.00	0.00	0.01	0.152
C18:1 t11	2.89 ^a	2.37 ^b	2.94 ^a	0.10	0.002
C18:1c9	15.4 ^a	13.7 ^b	14.5 ^{ab}	0.39	0.025
C18:1 c11	0.54	0.57	0.54	0.01	0.141
C18:2 n6	0.50	0.53	0.49	0.01	0.007
C20:0	0.10	0.09	0.10	0.0	0.007
C18:3 n3	0.60	0.63	0.61	0.01	0.213
CLA	1.13 ^a	0.83 ^b	1.01 ^a	0.04	<.001

Means within rows having different superscripts differ significantly ($P < 0.05$).

NITROGEN UTILIZATION

Cows in the FB treatment group had a lower ($P < 0.001$) apparent N intake compared with those in CON and OF treatments respectively. Partitioning of N to milk was also lower for FB as reflected by lower milk N and lower MUN (Table 5.7). Nitrogen use efficiency (NUE) was relatively high for all treatments, though FB had greater NUE than cows fed CON and OF respectively (Table 5.7).

Table 5.7. Mean apparent nitrogen intake, milk urea N, milk urea, N in milk, blood urea N, BHBA, NEFA, urinary urea, ammonia, creatinine, nitrogen %, and nitrogen use efficiency (NUE) of cows on ryegrass, FB and OF.

Items	CON	FB	OF	SEM	P value
Apparent N intake (g/cow/day)	431 ^a	338 ^c	423 ^a	4.85	<.001
N in milk (g/cow/day)	129 ^a	124 ^b	127 ^a	0.87	<.001
Milk parameter (mg/L)					
MUN	4.7 ^a	2.7 ^c	4.4 ^b	0.20	<.001
Urea	2.3 ^a	1.4 ^c	2.2 ^b	0.10	<.001
Blood parameter (mmol/L)					
BUN	7.3 ^a	4.1 ^c	6.7 ^b	0.42	<.001
NEFA	0.2	0.2	0.1	0.03	0.391
BHBA	0.7 ^b	1.1 ^a	0.7 ^b	0.08	<.001
Urine parameter					
Urine N concentration (g/L)	3.01 ^b	2.04 ^c	4.03 ^a	0.02	<.001
NH ³ (mmol/L)	2.0	1.8	2.6	0.49	0.291
Urea (mmol/L)	56.9 ^b	28.8 ^c	67.9 ^a	4.86	<.001
Creatinine (mmol/L)	2.1 ^b	2.4 ^b	3.1 ^a	0.27	0.001
Fecal parameter					
N (%)	3.5 ^b	3.9 ^a	3.6 ^b	0.09	0.001
Nitrogen use efficiency	0.298 ^b	0.362 ^a	0.295 ^b	0.003	0.001

¹CON = control (pasture only); FB = fodder beet; OF = oat forage

²MUN = milk urea nitrogen; BUN = blood urea nitrogen; NEFA = non- esterified fatty acid; BHBA= β -hydroxybutyrate acetate; PD = purine derivatives (allantoin + uric acid).

Blood samples reflected lower circulating urea, with cows in the FB treatment group having a lower ($P < 0.001$) plasma urea nitrogen concentration compared with those in OF and CON treatment groups. There were no treatment effects ($P = 0.391$) on NEFA concentration. Cows fed FB diet had higher ($P < 0.001$) BHBA concentration while OF and CON had lower.

The cows fed FB had a lower ($P < 0.001$) spot urinary N concentration (%) and lower urinary NH_3 , purine derivatives (PD), and urea concentrations compared with those of the cows fed CON and OF (Table 5.7). Creatinine value was higher ($P = 0.001$) in OF treatment, followed by FB treatment and lowest in CON treatment (Table 5.7). There was a significant difference ($P = 0.001$) in nitrogen use efficiency. Cows fed FB had higher values compared to cows fed CON and OF diets respectively (Table 5.7).

5.3. Discussion

5.3.1. INTAKE AND MILK YIELD

The current experiment demonstrated the repeatability of the first study supporting findings of a lack of milk response to FB supplement as shown in chapter 3 and also by Fleming et al., (2018). Despite the difference in total DM intake, the lack of an effect on milk solids production in this study probably reflects the high substitution rate particularly the FB treatment. When grazing cows are fed supplements substitution usually occurs and pasture DMI decreases (Kellaway and Porta, 1993; Bargo et al., 2003; Sheahan et al., 2011). The quality of FB was high compared to pasture and was expected to increase ME intake but instead increased pasture substitution rate.

The substitution rate (SubR) in this study was surprisingly high and showed that herbage intake by the supplemented treatment groups decreased by 1.45 for FB and 0.77 for OF. These values are far higher than those previously reported by Penno et al. (2006), with SubR of 0.17, 0.35 and 0.29 in early, mid and late lactation respectively

when cows were fed 25 kg DM/day in early lactation. Kolver (1998) reported higher SubR (kg pasture/kg supplement) of over 1 and St-Pierre, (2001) reported SR close to 1 when both using starch based supplements. More so, Fleming et al., (2018) reported similar SR with the one reported in this experiment when FB was supplemented in spring. Ideally larger responses to supplementation occur because animals increase total DMI and ME intake as a result of SubR below 1.0.

The high pasture SubR for the FB cows might be attributed to the type of ME (fermentable carbohydrates) provided by FB diet. Given the high sugar content and potential for lactic acid production in the rumen, there is a high possibility of disruptions to ruminal pH that affect the activity or number of cellulolytic bacteria. This can subsequently decrease the rate of fiber digestion of pasture (reduce hunger and motivation to eat), and herbage DMI (Dixon and Stockdale, 1999). Also, Previous studies investigated the effects of VFA on hepatic oxidation and satiety (hypophagia) and reported that infused propionate, but not butyrate or acetate (Knapp et al., 1992; Oba and Allen, 2003), lowered food intake. Oba and Allen (2003) ruminally infused propionate and reported a linear decrease in meal size 2.5 to 1.5 kg DM as propionate increased. Elliot et al. (1985) infused propionate and acetate separately into the mesenteric vein, and reported a decrease in DMI when propionate was infused, but no effect with acetate.

Stage of lactation might also be a reason for the high SR. At early phase after parturition, rumen volume is narrowed which makes substitution rate higher in early lactation (Gibb et al., 1992). However, this study was carried out from November to December, considerably longer than the 30 day post-partum period where cows are still to reach peak intake (de Vries and Veerkemp 2000). Few studies on the supplementation of fodder beet when fed with pasture during lactation of grazing dairy cows, demonstrates that fodder beet can be used to maintain milk production in early lactation.

Feeding fodder beet actually resulted in lower total apparent DMI by reducing the amount of pasture consumed. This is unusual given the intensity of grazing bouts on pasture were increased (Figure 5.2). The results (Table 5.3) shows that the daily

grazing/eating time on CON was 364 min (6.06 h), while the supplemented treatments (FB and OF) was 489 min (8.15 h) and 385 min (6.41 h) respectively. Statistically the large animal variation in grazing time was unable to reflect differences with 95% confidence, however numerically cows on FB or OF spent 35 minutes longer in eating activities. This may be linked to increased motivation to eat when cows are offered something new Gregorini et al (2006). Given that apparent intake was lower even though grazing duration was longer, suggests lower intake rate (g DM/minute), probably as a result of lower bite mass. Time spent grazing did not reflect on the total DMI as cows on CON treatment had higher DMI than the supplemented groups despite having the lowest time spent grazing. The fact that longer grazing time didn't improve apparent total DMI suggests that supplemented cows were displaying strong selective behavior when on pasture rather than trying to maximise intake rate. This agrees with (McEvoy et al., 2009) and Chilbroste et al., (2005), who reported that reduction in grazing time suggests that actual dry matter intake depend primarily on bite mass which basically is determined by herbage mass, allowance and structure. However, it differ with results obtained by Philips et al., (1995) were 23.7% increase in total daily DM intake was recorded when fodder beet was included in the diet of grazing cows.

There was no effect of supplementation or eating time on daily rumination ($P = 0.531$). The OF group spent more time ruminating (541 min/d), while the FB group had the lowest value (507 min/d), despite the fact that the CON group was the lowest in eating (min/d), the treatment group spent more time ruminating than the FB treatment. NDF is often regarded as a reliable indicator for chewing activity (Alberto et al., 2018) but in this study the herbage NDF among treatment group was similar, however, there was difference in the supplement offered, as OF had higher NDF than FB treatment (Table 5.1). The prolonged rumination in the OF group might be attributed to high NDF intake in the supplement diet compared to FB, there exist a positive correlation between daily NDF intake and rumination time (Metz, 1975). This result also agrees with Norgaard (1989) who stated substitutional relationship between eating and rumination.

5.3.2. MILK COMPOSITION

There is this huge consumer awareness that foods especially dairy products contain micro-components that may have valuable advantage on disease prevention and health maintenance (Adam and Bauman, 2004). Also, there has been extensive enthusiasm in the milk FA profile of grazing dairy cows, particularly in polyunsaturated fatty acid (PUFA) and conjugated linoleic acid (CLA) both of which have claimed human health benefits (Melendez et al., 2016). Typically, grazing dairy cows have higher concentrations of PUFA and CLA (cis-9, trans 11; CLA) in the milk compare to cows on total mixed rations (Elgersma, 2015; Barca et al., 2017). In this study, there was difference in CLA. FB had lower CLA values (0.83 g/100g fatty acid) compared to (1.13 and 1.01 g/100g fatty acid) for CON and OF treatments respectively (Table 5.6). This might be attributed to the difference in serum BHBA values with FB value > 0.7 compared to CON and OF (Table 5.7). Melendez, (2016) reported that early lactation cows with serum BHBA > 0.7 mmol/L tended to have higher milk fat % and had significantly lower concentrations of CLA than early lactation cows with BHBA ≤ 0.7 mmol/L). This relationship might be understandable since BHBA is used as substrate for milk fat synthesis in the mammary gland (Duffield et al., 2009).

Also, the ratios of cis-9, trans-11 CLA to trans-11 C18:1, and cis9 C18:1 to C18:0 were reduced by FB treatment showing a decrease of endogenously synthesized unsaturated fatty acid (UFA). This most likely indicates the decrease supply of trans-11 C18:1 in FB as the activity of delta 9 desaturase rely on substrate availability (Kay et al. 2002).

Another reason for low CLA in FB diet might be attributed to low fibre content (Table 5.2), which might lower the rumen pH and subsequently affect rumen functions, as observed by (Melendez et al., 2016; Huhtanen and Khalili, 1991), ruminant products contain high concentration of CLA because they are produced or synthesized from linolenic acid and dietary linoleic found in the rumen. This metamorphosis is possible due to major processes carried out by rumen microbes: lipolysis, biohydrogenation and isomerization. And the mechanisms mainly rely on the type and amount of fat entering the rumen and ruminal pH. Supplementing with sucrose has previously been

reported to decrease rumen pH and decrease the rate of NDF digestion (Huhtanen and Khalili, 1991; Chamberlain et al., 1993). In this study the nutritional composition of FB shows that it contains high sucrose contents.

More so, Bargo et al., (2006) reported similar results showing that supplementation with high sucrose or starch diet does affect CLA. In this study, FB had high soluble carbohydrate (sucrose) thus resulted in lower CLA. Results also support findings by (Fleming et al., 2018) who showed FB supplementation reduced CLA value.

Barca et al., (2017) reported that Supplementing grazing dairy cows may change the FA composition of milk fat, but there is substantial difference depending on the fat composition and content of the basal diet. In this study, the fatty acid results showed that inclusion of FB increased the total fat% in the milk (Table 5.5) which was driven by increases in C4:0, C6:0, C8:0, C10:0 and C10:1 compared to CON and OF treatments. Similar response to FB supplementation was observed by Fleming et al., (2018) who also showed increased short chain FA's when feeding FB. The main considerable changes in milk fat (MF) composition within early lactation takes place during the early weeks and become less considerable after week eight of lactation (Lake et al., 2007). Depending on the fat sources, (preformed FAs or de novo synthesis), as lactation progresses, the relative percentage of most de novo FAs (short and medium chain FAs) rises, whereas percentage of most preformed FAs (long chain FAs) reduces (Kay et al., 2005). In this study there was treatment effect on milk fat (%). FB had higher value of 4.8%, while CON had the lowest value of 4.2% and OF (4.5%), this might be due to the difference in serum BHBA among the treatment groups as FB had the highest value of 1.1 mmol/L (Table 5.7). This agrees with (Melendez et al., 2016) who observed that early lactation cows with serum BHBA > 0.7 mmol/L tended to have higher milk fat %. Another reason might be the fact that FB was stored before being fed which agrees with Bargo et al., (2002b) findings that milk fat (%) is typically lower for cows fed high quality pasture compared with cows receiving stored forages (FB).

The protein concentration of the milk of FB fed cows was high compared with the control. This was largely due to an increase in casein concentration – which accounts for 80% of the true protein in milk. Synthesis of casein requires calcium and this was

a mineral that was elevated in milk from cows supplemented with fodder beet. Interestingly, fodder beet as forage is regarded as being low in Ca, so elevated excretion of Ca into milk may indicate some homeostatic mechanism in response to Ca deficiency. Although mineral content of forages was not measured in this study, these results raise questions around links between supplementation and longer-term animal health.

5.3.3. N UTILIZATION

In this experiment NUE was very high ranging from 29-36%. The higher values may be explained by the low N concentration in herbage (16-17% CP) and for FB supplement (<10% CP) as observed in this study (late spring). Even though efficiencies as high as 38% in cows fed ryegrass-based diets have been reported Moorby et al., (2006), typical N use efficiencies reported in New Zealand for early lactation are 25% but can range from 15-40% (Calsamiglia et al., 2010). Review of trends over a wide range of management and dietary conditions shows that dietary crude protein concentration is the most important factor influencing the efficiency of N use (Huhtanen and Hristov, 2009). The N results of this study shows that there was no improvement in total milk solids as a result of supplementation with forage and catch crop. However, clear benefits were seen in terms of lower MUN, lower BUN, and lower urinary N excretion on FB treatment.

BUN and BHB evaluation provides an opportunity to determine the healthy production condition of the animals. This is known as blood profile test Nozad et al., (2012). It can also be used as an indicator of rumen N captured as these values are positively related to rumen ammonia concentrations (DePeters and Ferguson, 1992). BUN was lower for cows on FB compared with CON and OF (Table 5.7). The difference might contribute to the MUN values. This is in agreement with Lounglawan et al., (2011) whose findings showed that there is a strong positive correlation between blood urea nitrogen (BUN) and MUN. However, BUN values in this study is lower than the values obtained by Bargo et al., (2002b) who reported values averaging 17.2 mg/dL and Deloney et al., (2003) found average BUN values of 13.1 mg/dL.

Plasma NEFA was similar across treatments ($P = 0.391$). Plasma BHBA shows effect ($P < 0.001$) between treatments in this study. The values of plasma concentration of BHBA in all treatments were above the range of normal values for grazing dairy cows (averaging 1.01 mmol/L) 0.1 to 0.6 mmol/L are the acceptable range for early lactation cows (Wittwer, 2012; Raboisson et al., 2014). The high value in the FB treatment (1.2 mmol/L) might be the reason that cows were selective in grazing higher quality herbage under higher pasture allowance that resulted to high substitution rate (Table 5.4), similar result was reported by (Bargo et al., 2003; Morales et al., 2014). Another reason for the high concentrations of BHBA during this trial might be associated to the low herbage DM intake especially when supplemented preserved forage like FB treatment compared to CON and OF (Table 5.3); this agrees with past researches (Kellaway and Harrington, 2004; Perez-Prieto et al., 2011).

Urinary N (UN) concentration was lower ($P < 0.001$) in FB treatment (0.25%) compared with the CON (0.34%) and the OF treatment which had the highest UN concentration (0.44%). The reason for the low urinary concentration in the FB diet might be attributed to FB provided a lower CP% value (< 10) with corresponding lowest apparent N intake, which lead to low MUN. Several experiments have reported the excretion of N in urine to be directly related to N intake (Tas et al., 2006; Higgs et al., 2012). The CON and OF treatments diet had highest N intake, thus highest urinary and milk N output.

Another reason for differences in urinary and milk N concentration between treatments in this study was changes in the WSC:CP ratio. When the availability of WSC is comparatively low as observed in the CON and OF diets, either amino acids or structural carbohydrates of the plant are used by rumen microbes for the bulk of their energy supply and can lead to lack of both balance and synchronization of N and energy release in the rumen. This leads to accumulation of ammonia in the rumen, which is absorbed across the rumen wall and subsequently converted into urea before being excreted in the urine (Miller et al., 2001; Nocek & Russell, 1988).

The lower MUN, urea, BUN and urinary N concentration in FB treatment might be attributed to changes in the WSC:CP ratio. The higher WSC content of FB supplement

along with the lower CP content may enhance energy and protein supply to meet microbial requirements (Totty et al., 2013). Edwards et al, (2007a) reported that WSC:CP ratio of greater than 0.7 can lead to decrease in the amount of N intake thus urinary N excretion.

5.4. Conclusion

The results obtained in this study show little benefit (milk production) in supplementing early lactation cows with FB because both spring experiments showed decreased pasture utilization due to high substitution rate. However, feeding oats forage demonstrate the use of catch crops in addition to pasture to sustain milk production, while forage crop such as fodder beet increased milk fat %. There was clear benefit of N losses seen in fodder beet treatment especially reduction in urinary N concentration/losses.

Chapter 6

Feeding fodder beet and oats to evaluate performance and profitability using modeling.

6.1. Introduction

High level decision making for the economic and physical production of a farm seeks to address the challenge of meeting feed supply and demand requirements at the whole farm system level for a typical annual cycle. To overcome feed shortages technical and proactive decisions such as purchasing supplement feed, applying N fertilizer, and grazing off farm during the dry cow period (winter) help to balance the deficits in feed supply, enabling continued use of high stocking rates on the milking platform (Thorrold et al., 2004). An alternative to this system is to reduce animal demand by reducing stocking rates. For example, lower stocked systems typically have larger feed surplus and would result in large amounts of feed conservation if N fertilizer levels are maintained, although milk production per cow is higher, milk production per hectare will be reduced (Chapman et al., 2012b). While low stocking rate farms are producing less per hectare they are still maintaining profitability. These low stocking rate farms may be important for maintaining profitability while also reducing environmental footprint (Chapman et al., 2012b) as well as conserving forage as silage to reduce cost of feed importation.

The previous Chapters (3-5) have demonstrated the effect of using supplements such as fodder beet and oats crops on dry matter (DM) yield, milk production and N utilization at specific times of the year (early and late lactation). However, those studies were short term and the impact of altering supplementation strategy at the whole farm system level was not investigated in those experiments. Altering supplementation regime either by increasing farm system intensity (amount of

imported feed), or by buying or including cropping, has implications on the physical and financial performance. Consequently, managing risks associated with changing the system of a farm requires suitable strategic planning for the whole farm system.

Currently the commercial software tool with the capabilities for assessment of physical and financial farm performance is FARMAX Professional Dairy, decision support software designed for New Zealand dairy farm systems (Bryant et al, 2010). In this chapter (6), Farmax Dairy Pro, a derivative of the farm model Stockpol (Marshall et al., 1991) is populated with experimental data, to model the effects of productivity and profitability of feeding fodder beet and catch crop oats strategically on the milking platform. The scenarios evaluated were designed to offer alternative supplements in early and late lactation when pasture feed deficit occur.

6.1.1. RESEARCH OBJECTIVES

To determine the feasibility of integrating winter crops fodder beet and/or oats on productivity on the dairy milking platform

To compare the economic viability of using winter feeds as supplements relative to conventional supplementation in late and early lactation

6.2. Materials and methods

To compare alternative supplementation scenarios, a baseline farm representing a Canterbury irrigated dairy farm was set up in Farmax Dairy Pro (Version 6.6.5.00, Farmax Ltd) using their long-term model program. The assumptions for the baseline model farm were derived from Dairy Statistics NZ (2018) using North Canterbury figures for the 2018-2019 seasons. A physical description of the farm and the assumptions for pasture production are presented in Table 6.1. The pasture production assumed a Canterbury average yield for a range of soil types, with mean of 15.6 t DM/ha/yr.

6.2.1. ANIMALS AND LOCATION

The dairy breeds of cows on this property were Jersey-Friesian crossed and were mixed aged and had an average breeding worth of (90.6). Planned start of calving was 1 August on a target condition score of 5.0, with average live weight of 470 (kg) and dry off date in mid May. The heifer replacement policy was 20% with cull cows consisting of empty cows and low producers. Stock were assumed to be wintered off the milking platform, including all their replacement young stock.

Table 6.1. Physical description for the baseline model of North Canterbury for 2018-19 seasons.

FARMAX <small>YOUR ADVANTAGE</small> Physical Summary for Baseline <small>Jun 18 - May 19</small>			
Category	Description	Value	Units
Farm	Effective Area	234	ha
	Stocking Rate	3.5	cows/ha
	Comparative Stocking Rate	84.7	kg Lwt/t DM offered
	Potential Pasture Growth	16.7	t DM/ha
	Nitrogen Use	200	kg N/ha
	Feed Conversion Efficiency (offered)	9.9	kg DM offered/kg MS
Herd	Cow Numbers (1st July)	650	cows
	Peak Cows Milked	824	cows
	Days in Milk	263	days
	Avg. BCS at calving	5.1	BCS
	Liveweight	1,251	kg/ha
Production (to Factory)	Milk Solids total	347,954	kg
	Milk Solids per ha	1,487	kg/ha
	Milk Solids per cow	422	kg/cow
	Peak Milk Solids production	2.29	kg/cow/day
	Milk Solids as % of live weight	118.8	%
Feeding	Pasture Offered per cow *	3.2	t DM/cow
	Supplements Offered per cow *	0.3	t DM/cow
	Off-farm Grazing Offered per cow *	0.6	t DM/cow
	Total Feed Offered per cow *	4.2	t DM/cow
	Pasture Offered per ha	11.5	t DM/ha
	Supplements Offered per ha	1.4	t DM/ha
	Off-farm Grazing Offered per ha	5.3	t DM/ha
	Total Feed Offered per ha	18.2	t DM/ha
	Supplements and Grazing / Feed Offered *	22.6	%
	Bought Feed / Feed Offered *	4.5	%
(*) feed offered to females > 20 months old / peak cows milked			

6.2.2. Economic assumptions

Milk solids income for the initial financial projections was based on a milk payout of \$6.00/kg MS. The budgeted expenditure used the program default values for Canterbury to calculate the variable expenses which largely depend on cow numbers (such as animal health and breeding). All fixed costs such as administration, rates and insurance were based on the 2018/2019 North Canterbury budget (Table 6.1). The cost of N fertilizer was based on the long-term average price of urea (\$475/ton) and \$12/ha for cartage and spreading (www.ravensdown.co.nz 2018). The cost of non-N fertilizer was based on the budgeted figure for the North Canterbury, with an adjustment made for the proposed scenarios based on the remaining area of pasture. The cost of non-N fertilizer for the crops using model default values were included in the budgeted crop expenditure. Modifications were made for the rise in machinery costs for the feeding out of fodder beet bulb and oats silage and harvested fodder beet. The cost of grazing included the heifer calves, rising one-year-old heifers and winter grazing of rising two-year-old and mixed-aged cows. It was assumed wages would not increase or decrease for any of the scenarios. Pasture silage was imported at \$0.34 cents/kg DM or was made on-farm for \$340/ha.

6.2.3. SCENARIO ASSUMPTIONS

Table 6.2. Supplementation regimes in the four scenarios using fodder beet and/or oats in spring and autumn

Scenarios/Months	J	J	A	S	O	N	D	J	F	M	A	M
Scenario 1			FB spring									
Scenario 2			OF spring							FB autumn		
Scenario 3			OF spring									
Scenario 4										OS autumn		

The scenario assumptions modeled in Farmax Dairy Pro were based on experimental results of two springs and one autumn feeding trial (Chapters 3 to 5). When conducting these scenarios – days in milk was held constant (same as the baseline) so only milk yield and supplementation were able to vary and cultivated area was 10.2 ha. For the spring calving system the amount of supplementation was limited to ensure pasture cover did not exceed 2800 kg DM/ha (to maintain pasture utilization and quality). Similarly, combined supplement import and off farm grazing as a proportion of feed offered (t DM/ha) would not alter by more than 15% from the baseline in any of the scenarios. The goal was not to change the farm system in the scenarios but to optimize supplementation practices by integrating current wintering feeding regimes with those on the milking platform. All scenarios are summarized in Table 6.2 with specific detail to follow:

Scenario 1 (Spring)

In Chapter 3 research results showed that supplementing with FB bulb in spring maintained milk yield, sparing pasture. So the first scenario compared the baseline farm (feeding ryegrass + ryegrass silage) with an alternative spring supplementation regime of feeding FB bulb. It was assumed that FB was pulled and carried from the winter block at a cost of 12.1c/kg DM and that little transition was required due to FB making up their winter diet. Figure 6.1 depicts each feed type and quantity offered each month. For instance FB was fed at 4.0 kg DM/cow/day in August (A) September and October and at 3.1 kg in November and pasture silage was fed in late lactation.

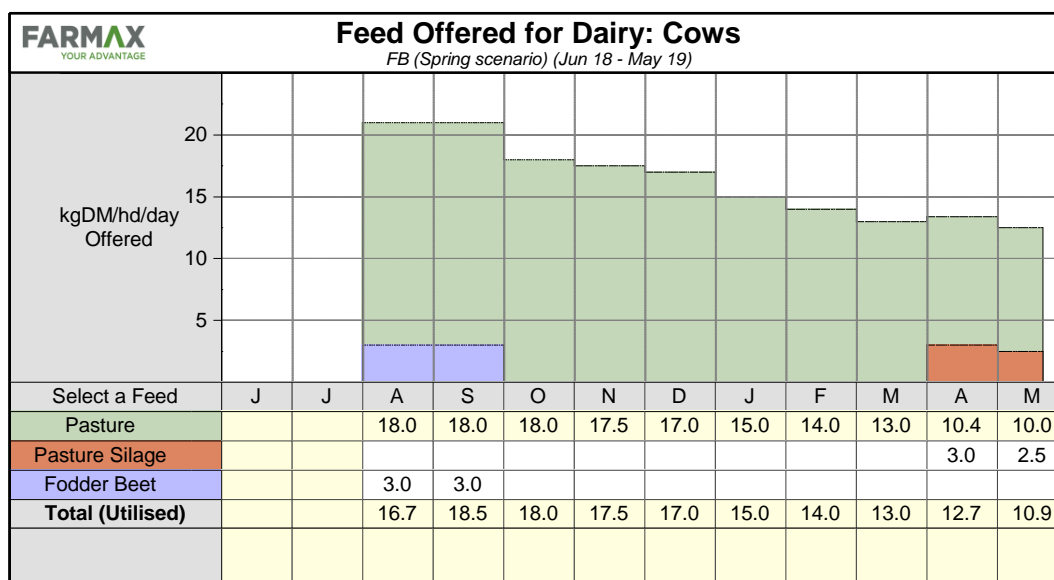


Figure 6.1. Feed offered by month and total feed utilized by lactating cows for FB bulb spring scenario

Scenario 2

In Experiment 2 (simulating results of Chapter 3, 4 and 5) we found that FB (grazed in situ) in autumn (chapter 4) also supported milk yield. As part of the pasture replacement program in this scenario, the FB was grown on the milking platform (sown late spring) with winter oats drilled after FB (winter) and grazed in spring (chapters 3 & 5). Surplus pasture in spring or summer was conserved as pasture silage. Allocation of this crop is shown in Figure 6.2 and Table 6.2.

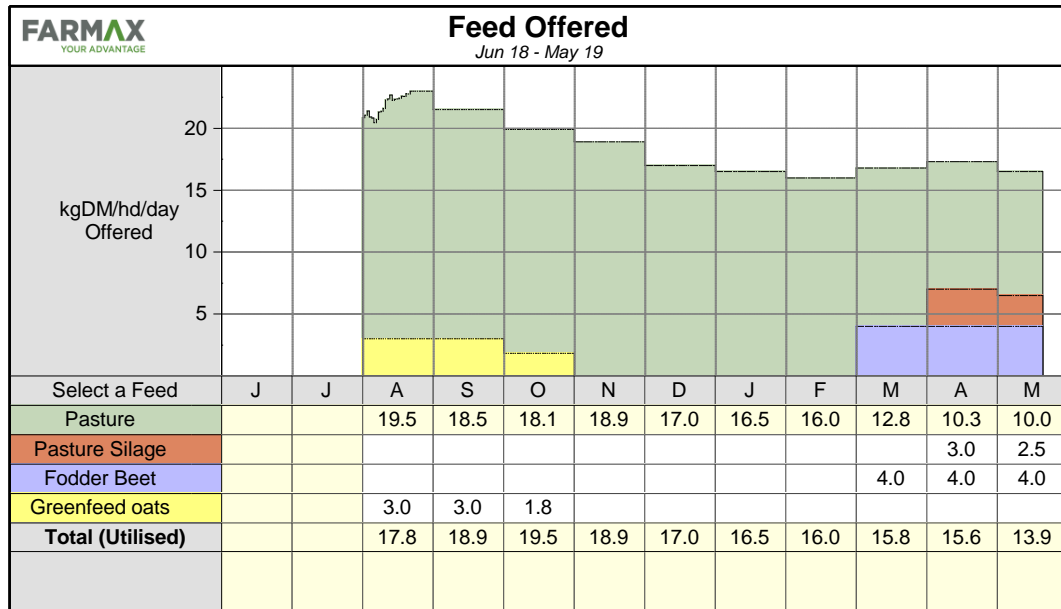


Figure 6.2. Feed offered by month and total feed utilized by lactating cows for oat in spring and FB (grazed) autumn scenario

Scenario 3

An alternative scenario was to exclude FB as a supplement as results of Experiment 3 (Chapter 5) showed that OF fed in spring also supported milk production. As with Scenario 2, the third scenario included a crop as part of the pasture renovation program but only included OF (Figure 6.3). Oats sown/drilled on 10.2 ha of land in mid June and offered as captured in (Figure 6.3)

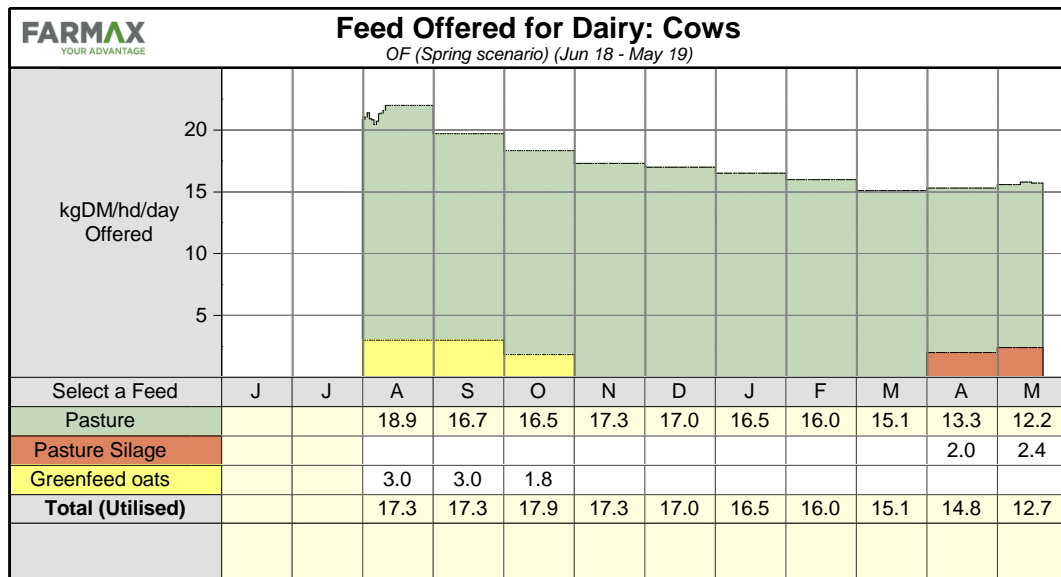


Figure 6.3. Feed offered by month and total feed utilized by lactating cows for OF spring scenario

Scenario 4

In scenario 4 the results of Chapter 3 are simulated where conserved oats as silage or baleage (OS) were also shown to support milk production in late lactation. Oats was sown in July as part of a pasture renewal program and rather than graze the oats that requires rumen transition and additional labor in stock movement, the oats were harvested for silage in September. After ensiling the oats area was re-grassed and returned to permanent pasture sooner than if the area was grazed. The silage was fed out in autumn between March- May (Figure 6.4.).

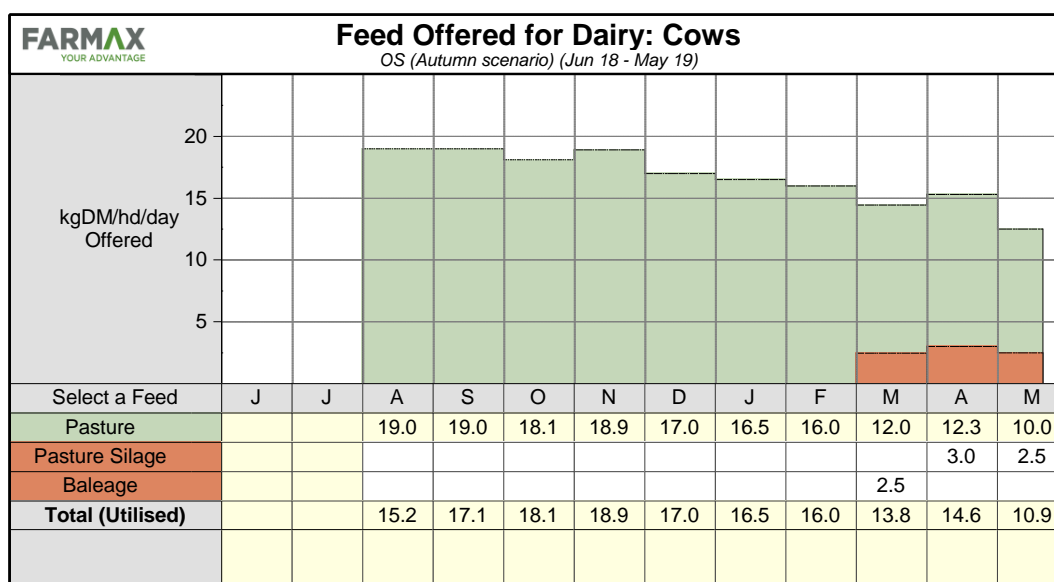



Figure 6.4. Feed offered by month and total feed utilized by lactating cows for OS autumn scenario

6.3. Results

6.3.1. Pasture production and feed supply

The results obtained from the 4 scenarios as captured in table 6.3, showed that under same stocking rate of 3.5 and potential pasture growth rate of 15.6 t DM/ha (Table 6.3). Supplement supply between scenarios and seasons is shown in (Table 6.3). The supplement eaten by the FB & OF scenario farm was 0.4t DM/cow, followed by FB (spring scenario) with 0.3 t DM/cow, then the OF and OS farms had similar (0.2t DM/cow) (Table 6.3).

Table 6.3: Physical description of all farms

		Compare Physical Summary for All Farms <i>Jun 18 - May 19</i>					Units
Category	Description	Baseline	FB (Spring scenario)	FB & OF (Autumn & Spring scenario)	OF (Spring scenario)	OS (Autumn scenario)	
Farm	Effective Area	234	234	234	234	234	ha
	Stocking Rate	3.5	3.5	3.5	3.5	3.5	cows/ha
	Comparative Stocking Rate	84.7	87.2	80.2	81.8	84.1	kg Lwt/t DM offered
	Potential Pasture Growth	16.7	15.6	15.6	15.6	15.6	t DM/ha
	Nitrogen Use	200	200	200	200	200	kg N/ha
	Feed Conversion Efficiency (offered)	9.9	9.8	9.8	9.8	9.8	kg DM offered/kg MS
Herd	Cow Numbers (1st July)	650	650	650	650	650	cows
	Peak Cows Milked	824	824	824	824	824	cows
	Days in Milk	263	264	264	264	264	days
	Avg. BCS at calving	5.1	5.0	5.0	5.0	5.0	BCS
	Liveweight	1,251	1,265	1,281	1,245	1,260	kg/ha
Production (to Factory)	Milk Solids total	347,954	344,408	380,336	362,315	359,004	kg
	Milk Solids per ha	1,487	1,472	1,625	1,548	1,534	kg/ha
	Milk Solids per cow	422	418	462	440	436	kg/cow
	Peak Milk Solids production	2.29	2.39	2.42	2.25	2.30	kg/cow/day
	Milk Solids as % of live weight	118.8	116.4	126.9	124.4	121.8	%
Feeding	Pasture Offered per cow *	3.2	3.2	3.3	3.4	3.4	t DM/cow
	Supplements Offered per cow *	0.3	0.2	0.5	0.3	0.2	t DM/cow
	Off-farm Grazing Offered per cow *	0.6	0.7	0.7	0.7	0.7	t DM/cow
	Total Feed Offered per cow *	4.2	4.1	4.5	4.3	4.3	t DM/cow
Diagnostics	Pasture Offered per ha	11.5	11.3	11.8	12.0	11.9	t DM/ha
	Supplements Offered per ha	1.4	1.1	2.1	1.2	1.0	t DM/ha
	Off-farm Grazing Offered per ha	5.3	5.5	5.5	5.5	5.5	t DM/ha
	Total Feed Offered per ha	18.2	17.9	19.4	18.7	18.4	t DM/ha
	Supplements and Grazing / Feed Offered *	22.6	22.2	26.5	21.6	21.0	%
	Bought Feed / Feed Offered *	4.5	0.0	0.0	0.0	0.0	%
(*) feed offered to females > 20 months old / peak cows milked							

6.3.2. Animal production

Compared with the baseline, all scenario's except FB spring resulted in increased feed per cow (Table 6.3) which corresponded with more milk yield compared with the baseline farm. There was a 8.3%, 4.1%, and 3.2% increase in milk yield over baseline farm for scenarios 2, 3 and 4 respectively and decrease in milk production for scenario 1. There was no change in stock numbers or lactation length (days in milk).

The distribution of milk yield is demonstrated in figure 6.6. For scenario 2 (FB and OF grown on farm), supplementation was used to maintain milk production in late lactation.

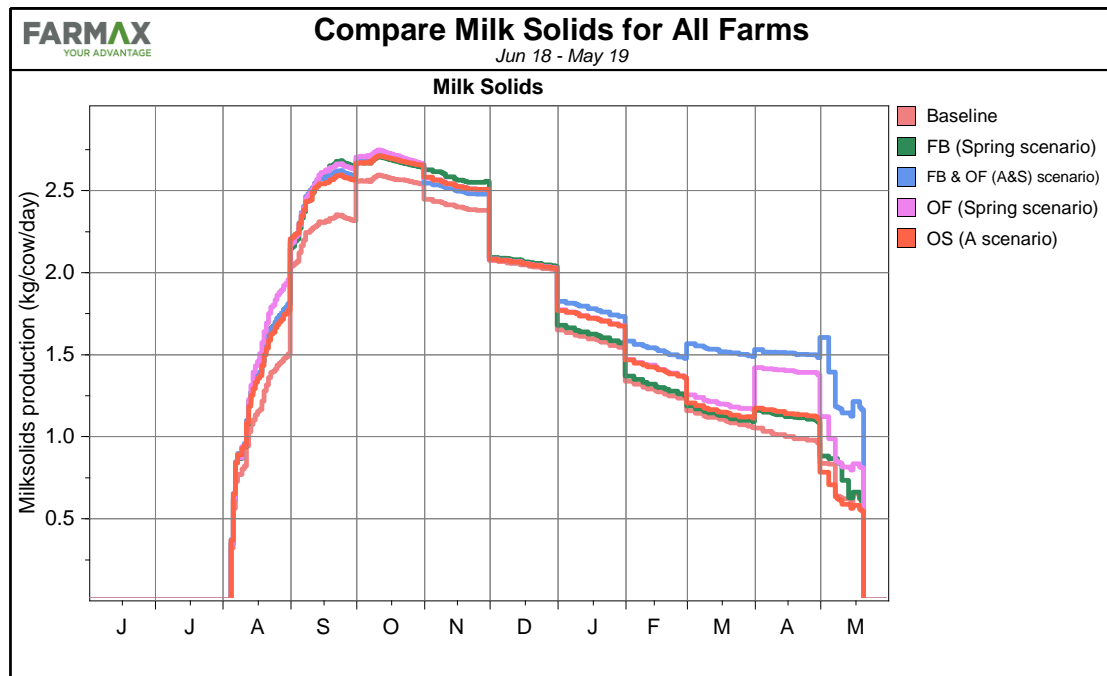


Figure 6.6: Average daily milk production per cow by months

6.3.3. Profitability

The FB & OF (A&S, Scenario 2) farm was more profitable while the baseline had the least profit (Table 6.4). The gross margin showed that the FB & OF (A&S) farm had the highest financial profit while the FB spring (scenario 1) had the least among the farm scenarios. The gross margin per ha shows there was 10.1%, 6% and 4.4% profit increase for FB & OF, OF and OS scenarios respectively also the FB & OF scenario had the highest total revenue compared to the baseline. The total variable expenses also shows that the FB & OF scenario had the highest and the baseline with the lowest.

Table 6.4: Compared gross margin for all scenarios

FARMAX YOUR ADVANTAGE		Compare Gross Margin for All Farms					
		Jun 18 - May 19					
		Baseline	FB (Spring scenario)	FB & OF (Autumn & Spring scenarios)	OF (Spring scenario)	OS (Autumn scenario)	
Revenue	Stock	Sales - Purchases	85,550	96,353	100,568	98,708	98,207
		Milk (Standard)	1,732,995	1,712,189	1,926,466	1,819,107	1,799,329
		Total Stock	1,818,546	1,808,541	2,027,034	1,917,815	1,897,536
	Crop & Feed	Capital Value Change	12,035	-2,492	-2,492	1,570	-2,492
		Total Feed	12,035	-2,492	-2,492	1,570	-2,492
Total Revenue		1,830,581	1,806,049	2,024,542	1,919,385	1,895,043	
Expenses	Crop & Feed	Conservation	32,175	12,870	12,870	12,870	22,559
		Forage Crops	0	57,518	60,000	12,240	0
		Purchased Feeds	6,405	0	0	0	0
		Calf Feed	4,113	4,090	4,090	4,090	4,090
		Nitrogen	100,152	100,152	100,152	100,152	100,152
		Off-Farm Grazing	245,565	273,888	273,888	273,888	273,888
		Total Crop & Feed	388,409	448,518	451,000	403,240	400,689
	Stock Costs	Animal Health	59,475	59,614	59,614	59,614	59,614
		Breeding	19,982	19,982	19,982	19,982	19,982
		Farm Dairy	13,003	13,023	13,023	13,023	13,023
		Electricity	30,451	30,451	30,451	30,451	30,451
		Total Stock Costs	122,911	123,070	123,070	123,070	123,070
	Interest on Capital (livestock & feed)		149,083	147,478	147,478	147,521	147,789
	Total Variable Expenses		660,403	719,065	721,548	673,831	671,549
Gross Margin		1,170,177	1,086,984	1,302,994	1,245,554	1,223,495	
Gross Margin per ha		5,001	4,645	5,568	5,323	5,229	

6.4. Discussion

The purpose of this study was to look at the profitability of integrating winter crops – identified as effective feeds for reducing nitrate losses – on to the milking platform at the whole farm system level. Proof of concept research, which supplemented dairy cows with fodder beet or oats or conventional pasture silage demonstrated that at times of the year these crops are useful for maintaining or improving milk yield. From

an economic point of view we modelled the viability of growing these crops on the milking platform.

Scenario 1 is the replication of field trials 1 and 3 i.e. (chapter 3 & 5). It represented the cultivation of fodder beet on the milking platform instead of importing residual winter crop to be fed out in spring. The spring fed fodder beet bulb effectively replaced pasture in the animal demand until the beginning of December. As a result, there was a surplus of pasture that was conserved as pasture silage and later fed out in autumn. Total feed supply increased by almost 47 t DM, but resulted in decrease in milk production compared to the baseline. The limitations of scenario 1 are cows supplemented FB have high substitution rate of 0.86 (Figure 6.1). Which overtime affects herbage intake as observed in Table 6.3. FB spring scenario had the lowest pasture intake. More so, if supplementation reduces pasture utilization, it may also reduce feed quality in subsequent grazing cycles.

The second (2) scenario represented a slightly more complicated farm system that opted to include the crops as part of the pasture replacement program on the milking platform. In the research experiments (Chapters 3 and 5) grazed oats in spring while fodder beet was grazed in autumn and were effective at supporting milk yield due to high quality. The modeled results showed grazing oat forage in spring effectively removed pasture from the feed supply until December. Therefore, there was surplus of pasture, which was conserved as pasture silage and later used in autumn. This scenario shows an additional 1.7% increase in conserved pasture compared with baseline scenario. The total feed supply increased by almost 50 t DM which in turn increased milk production by 8.3%. The substitution rate under this scenario was 0.27 (Figure 6.2), which is very low and shows pasture was well utilized compared to scenario one.

The third (3) scenario is a situation observed in chapters 3 & 5, where oat is drilled during period of extreme low temperature and pasture growth is slow. The oat forage was grazed in late spring until November when pasture quality is been compromised. With a moderate substitution rate of 0.65 (Figure 6.3), the surplus pasture was also conserved as pasture silage and fed out during autumn. This scenario added 1.7% of

pasture silage compared to baseline. The total feed supply increased with 24.5 t DM, which in turn increased milk production by 4.1%. The limitations observed with this scenario is high growth rate when oats crop attain full canopy closure, this condition leads to more fibrous and stemmy oat that affects the quality.

Scenario 4 represent late lactation (chapter 4) situation where the excess oat crop utilized in late spring was conserved into oat silage and used in autumn (late lactation) to support feed need and prolong lactation length (Figure 6.4). With a substitution rate of 0.6, this scenario increased total feed supply by 24.5 t DM of oat silage, which in turn increased milk production by 3.2%.

Milk production

In scenario 1, fodder beet spring scenario decreased milk production by 1% compared to the baseline scenario. This decrease in milk production is probably attributed to decrease in pasture utilization. There was decrease of 1.6% of feed DM eaten/ha compared to the baseline (Table 6.3), this decrease in feed intake led to decreased milk production. Similar results were reported in chapters 3 and 5, as FB cows had reduced herbage DM intake due to high substitution rate which also led to low milk production compared to control treatment.

Scenario 2 combined chapter 4 fodder beet autumn grazing and chapters 3 & 5 spring grazing of oat forage. The results in chapter 4 showed that there was no difference in milk production between the FB (grazed) and Control treatments. Similarly, the results in chapter 5 showed there was no difference in milk production between the grazed oat forage and control treatments. However, in the Farmax scenario 2, the results showed that there was difference in milk production. The OF spring grazed and FB (autumn grazed) scenario had an increase of 8.3% in milk production than the baseline. This might be attributed to the amount (kg DM) offered, intake and feeding regime as well as high feed utilization. Table 6.3 shows that scenario 2 had increase of 6.2% feed eaten/ha compared to baseline scenario. Another factor might be the feeding regime and the long-term effect on supplementing FB and OF especially the effect of sustaining milk production in autumn (Figure 6.6).

Scenario 3 was same as chapter 5 where OF was grazed and supported milk production in spring. No difference in milk production was observed in chapter 5 grazing trial after 21 days of the trial. However, there was difference in the Farmax scenario. In this scenario, feeding OF in spring increased milk production by 4.1% compared to baseline scenario. The reason might be attributable to amount (kg DM) of feed eaten. The feed eaten/ha in this scenario increased by 2.6% compared with baseline. Another reason might be the period of feeding. In chapter 5 oat forage was offered at 3 kg DM/cow/day for 14 days after 7 days of adaptation while in the Farmax scenario showed that oat forage was offered at 2 kg DM/cow/day (Figure 6.3) for 90 days (Table 6.2).

Scenario 4. In Chapter 3, oat silage also supported milk production in spring, but there was no difference with the Control. While in chapter 4, OS could not support milk production in late lactation (Autumn) compared to the control treatment. However, in the Farmax scenario the oat silage spring scenario 4 showed that there was increase of 3.2% in milk yield compared to the baseline scenario. This might be attributed to the total feed eaten there was increase of 1.1% of the total feed eaten/ha in this scenario compared to the baseline scenario. More so, feeding period/length might have contributed to the increase in milk production. These results showed that using OS for long-term supplementation is more productive and profitable in terms of milk production than short-term trial.

Overall, the results obtained in the scenarios were inconsistent with the results obtained in the field trial in terms of pasture intake and utilization which resulted into no difference with the control treatment in terms of milk production especially the FB treatment where high substitution of herbage was reported as well as OF treatment (early and late lactation) where the quality of the silage was poor. These inconsistencies might largely be attributed to stocking rate (SR). With conventional pastures species, stocking rates need to be higher in order to maintain pasture utilisation and quality at a high level (Gicheha et al., 2012). The modeling scenarios had a higher stocking rate of 3.5 compared to the field trial of 2.8. Therefore, pasture utilization were higher in the modeling scenarios than field trial.

6.5. Summary of milk production

On the overall farm scenarios performance, the results compared by FARMAX showed that the FB & OF (autumn & spring) farm scenario had the highest milk production (Table 6.3), it was closely followed by OF spring, OS and baseline scenarios respectively. Farmax showed that the FB spring farm scenario had the lowest milk production. The likely reason can be attributed to poor feed utilization, (Table 6.2) showed that the FB & OF (autumn and spring) farm scenario had the highest (17.6 t DM/ha) accounting for 23.9% of total feed eaten compared to the other scenarios. The OS (autumn) farm scenario had (total feed eaten) of 18.4 t DM/ha but with less MS production compared to the FB (spring) farm scenario that had 17.9 t DM/ha. Overall, the FB spring scenario had the lowest 17.9 t DM/ha total feed eaten with corresponding lowest (418 kg/cow) MS production to factory. Another factor that might be responsible for high MS production in FB and OF scenario is the advantage of superior ME of (13.5 and 12.5) respectively, couple with high utilization rate resulting in a significant increase in milk production compared with OS and Baseline with ME of (9 and 11) respectively. Also, the high feed quality of the FB & OF farm scenario resulted to increased feed conversion efficiency (FCE) compared with other scenarios.

Profitability

The financial performance of all the scenarios is governed by production economies. Profitability is maximized by increasing the level of inputs until cost of doing so equals the additional income generated from the additional input (Martin and Woodford, 2005). Of note, this study found that all the scenarios were more profitable compared to the baseline. However, the most profitable systems were those with the highest milk production per hectare, with additional revenue compensating for the cost of the supplement (Table 6.4). The gross margin for all farms showed that the FB & OF (Autumn & Spring) farm scenario is the most productive and profitable system with an increase of 10.1% gross margin profit/ha. This was closely followed by the OF and

OS, scenario's with corresponding 6% and 4.4% gross margin profit/ha respectively compared with the baseline scenario.

Under a \$6.00/kg MS with similar stocking rate (3.5), same potential pasture growth rate (15.6 t DM/ha), and days in milk (264 DIM). It is safe to say that the high milk production which led to high profitability was driven by the lowest cost/kg MS (\$3.70/kg MS) and highest MS production to factory for the FB & OF (A&S) farm scenario (Table 6.3).

The increased milk production to factory by the FB & OF (A&S) and the other assumption scenario farms resulted in a lower cost of production compared to baseline. The fixed costs of the system were spread out over more milk solids. The fixed costs were deemed to be wages, R&M land/buildings, vehicle expenses etc. in this study, it showed that the greater milk production on the FB & OF (A&S) scenario farm and other assumption scenarios farms reduced the fixed costs on a per kg MS basis. Table 6.4 shows that the greater milk production on FB & OF (A&S) farm scenario reduced the fixed costs on per kg MS basis on wages with \$.04 cents/kg MS and \$.06 cents/kg MS on grazing. This might account for a huge difference in the overall expenses compared to the baseline.

Aside the high MS production to factory and at lowest cost of production, this study showed that FB & OF (A&S) farm scenario had more forage crop yield compared to FB only, OF and OS scenarios (Table 6.4). It is also interesting to note that, no feed was purchased in all scenarios that is another reason that led to reduce cost of producing MS across all scenarios.

6.6. Conclusions

Under the assumption that milk revenue across a volatile commodity market is conservative at \$6.00/kg MS, integrating crops such as FB & OF (A&S) in a conventional system of Canterbury dairy farm is productive and profitable. Therefore, given the objectives of this study it is very profitable to use crops (forage crops (oats) and fodder beet) in the milking platform preferably the oats be grazed in spring (early lactation) after which the fodder beet be sown after grazing oats and grazed in autumn (late lactation) in addition to pasture. The crops rotation sequence of FB after oat significantly increased milk production with the lowest cost of producing to factory kg MS in a long-term supplementation plan, as well as producing the highest forage yield. Compared to the short-term trial, the high productivity achieved which led to significant profit probably is as a result of DM allocation by growing more feed as observed as well as high stocking rate that resulted in high pasture utilization in the modeled scenarios than field trials.

Chapter 7

General discussion and conclusion

7.1. Introduction

This thesis examined the effect of integrating winter crops (recommended for reducing N losses on winter systems), on the milking platform as an early or late lactation supplement for dairy cows. The effect of supplementing fodder beet or oats on dry matter intake (DMI), milk yield, milk composition, and N partitioning was carried out in three grazing experiments and using Farmax modeling. As outlined in the introduction of this thesis, the broad objectives of this study were to measure: utilization, DM intake, milk production, grazing behavior, N utilization as well as modeling farm scenarios using FARMAX dairy pro to determine the effect of fodder beet or oats supplementation on economic sustainability.

7.2. Milk production

Milk solids (MS) results of both early lactation trials (early and late spring) showed there was no treatment effect on MS production. The lack of an effect on MS production in both spring studies reflects the similarity in total DM and energy intake across treatments. When grazing cows are fed supplements substitution usually occurs and pasture DMI decreases (Kellaway and Porta, 1993; Bargo et al., 2003; Sheahan et al., 2011). A key factor determining milk response to supplement is substitution rate (SR), which affects total intake of DM and ME. In chapter 3 (early spring trial), the supplemented treatment groups had greater DM intake than CON, but in chapter 5 (late spring trial) the DMI results shows that the supplemented treatments had lower DM intake than CON. In both experiments, there was high herbage SR, particularly for those supplemented with FB. Herbage substitution rate as high as 1.5 and 0.8 for FB and OF was observed respectively. Fleming et al., (2018) reported similar results when FB was supplemented in spring. The grazing behavior

sensors indicated that the time spent grazing was similar across treatments, though variation in the herbage residual would indicate that the intensity of grazing by FB cows must have declined. Based on the lack of milk response to supplement of both spring studies, supplementing with fodder beet or oats in early lactation was not recommended where no feed deficit exists. Pasture utilization was compromised when supplements were fed with no gain in milk production – with long term negative effects on pasture quality.

On the other hand, in chapter 4 (autumn experiment) results showed that supplementing with FB compared favourably with the RGS (control) with regards to milk production, while the OS reduced milk solid production - despite having the highest DM intake. This was attributed to both poor quality of supplement and high pasture mass for cows in the OF groups.

7.2.1. Milk composition and quality

From a health point of view, milk with increased protein or minerals such as calcium or healthy fats such as many long chain fatty acids may be easier to market. In Chapter 5, supplementation with FB resulted in increased Casein concentration. This difference might be attributed to mineral imbalance and the mobilization of Ca from bone due to deficiency shortly after transition. In the two spring experiments there were inconsistent milk composition response. In early spring (Chapter 3) there was no effect on milk composition but in late spring (chapter 5) FB had higher milk fat (4.8%), then OF (4.5%), or CON (4.2%), similar results were reported by Fleming et al., (2018) who also noted low CLA from feeding fodder beet. In this study, FB had lower CLA values (0.83 g/100g fatty acid) compared (1.13 and 1.01 g/100g fatty acid) with CON and OF treatments. This might be attributed to the difference in serum BHBA values with FB value > 0.7 compared to CON and OF. Melendez, (2016) concluded that early postpartum cows with serum BHBA > 0.7 mmol/L tended to have higher milk fat % and had significantly lower concentrations of CLA than early postpartum cows with BHBA ≤ 0.7 mmol/L). Another reason for low CLA in FB diet might be attributed to low fibre content, which might lower the rumen pH and subsequently affect rumen

functions, as observed by Melendez et al., (2016). Also, the ratios of cis-9, trans-11 CLA to trans-11 C18:1, and cis-9 C18:1 to C18:0 were reduced by FBB treatment indicating a reduction of endogenously synthesised UFA. This most likely reflects the lower supply of trans-11 C18:1 in FB as the activity of delta 9 desaturase is dependent on substrate availability (Kay et al. 2002).

7.2.2. Nitrogen utilization

One concern with grazing cows in the South Island is the potential for high nitrogen losses as nitrate to soil water. Dairying systems contribute a disproportionately high amount of the total N leaching losses in dairy systems. Thus, there is a need to identify forage system approaches that reduce N excretion in urine.

In chapter 3 and 5 (spring experiments), the low CP content of FB continued to provide benefits in reducing N losses as reflected by the low MUN and low urinary N concentration compared with other supplements and CON. Although an increase in total milk yield was not seen as a result of the supplementation of FB and oats, apparent reduction was observed in urinary N excretion especially the FB treatment groups. In Chapter 3 and 5, the results for NUE were both high, averaging 29-36%. The FB cows had an increase of 17.7% NUE compared to CON. The higher values may be explained by the low N concentration in herbage (16-17% CP) and for FB supplement (<10% CP) as observed in these studies (early and late spring). The reduction in urinary N excretion in FB cows aligned with low MUN, BUN perhaps as a result of high WSC and low N in the diet. Trends evaluated over a wide range of dietary and management conditions indicate that dietary CP concentration is the most important factor influencing the efficiency of N use (Huhtanen and Hristov, 2009).

A low NUE was observed in grazing dairy cows in autumn, which is attributed to the high CP of perennial ryegrass and white clover during early and late lactation (Juan and Rene, 2011). However, the results obtained in autumn trial (Chapter 4), shows that FB had a higher NUE with an increase averaging 8% between ryegrass silage (CON) and OS despite having a higher N intake of .3% and 7.3% compared to RGS and OS.

The reason for the high NUE in FB cows is attributed to both the low protein content of the diet and the high metabolisable protein demand of these cows in peak lactation.

The results obtained in the 3 grazing experiments in early and late lactations shows that integrating winter crops as a supplement for early and late lactation dairy cows can reduce N excretion as much as has been observed during winter (Edwards et al., 2014).

However, the results of these studies demonstrate the implications for timing of feeding of forages or crops - designed to improve environmental effects in winter - on short and long term effects on milk and pasture production. When there is a surplus of high quality pasture it would be more prudent to avoid supplementation and manage pasture utilization. We suggest that conserving oats for supplementation during a feed deficit is a more appropriate use for a catch crop and that FB is supplemented when pasture supply is in deficit or when reductions in urinary N loss are warranted, as the bulbs are stored in windrows 2.5m high and 6m wide, and have been successfully used for 4-5 months after harvesting without requirement for cover (Gibbs, 2011).

7.3. Economic sustainability

The financial performance of all the scenarios is governed by production economies. Of note, this study found that all the scenarios were more profitable compared to the baseline (CON). However, the most profitable systems were those with the highest milk production per hectare (Table 6.4), the gross margin for all farms showed that the FB & OF (Autumn & Spring) farm scenario is the most productive and profitable system with an increase of 10.1% gross margin profit/ha, this was closely followed by the OF and OS scenario's with corresponding 6.0% and 4.4% and 4.6% gross margin profit/ha respectively compared with the baseline scenario.

Under a \$6.00/kg MS with similar stocking rate (3.5), same potential pasture growth rate (15.6 t DM/ha), and days in milk (264 DIM). It is safe to say that the high milk production which led to high profitability was driven by the lowest cost/kg MS

(\$3.70/kg MS) and highest MS production to factory for the FB & OF (A&S) farm scenario. The increased milk production to factory by the FB & OF (A&S) and the other assumption scenario farms resulted in a lower cost of production compared to baseline. The fixed costs of the system were spread out over more milk solids. The fixed costs were deemed to be wages, R&M land/buildings, vehicle expenses etc. in this study, it showed that the greater milk production on the FB & OF (A&S) scenario farm and other assumption scenarios farms reduced the fixed costs on a per kg MS basis. Table 6.4 showed that the greater milk production on FB & OF (A&S) farm scenario reduced the fixed costs on per kg MS basis on wages with \$.04 cents/kg MS and \$.06 cents/kg MS on grazing. This might account for a huge difference in the overall expenses compared to the baseline.

Aside the high MS production to factory and at lowest cost of production, this study showed that FB & OF (A&S) farm scenario had more forage crop yield resulting to high pasture conservation compared to FB only, OF and OS scenarios. It is also interesting to note that, no feed was purchased in all the scenario which is another reason that led to reduced cost of producing MS across all scenarios.

7.4. Conclusion

These findings indicate that pasture is likely to be spared if farmers use crops in early lactation to aid transition due to high SR. The results obtained in the autumn experiment shows that dairy cows on pasture supplemented, high energy diets like FB during late lactation (chapter 4) can meet the cows nutritional and DM need, maintain milk production and increase length of lactation. Also, FB diet reduced urinary N excretion compared with RGS and OS. Despite the increased in milk fat (%) in FB cows, results showed low CLA value. In addition, results in the 3 grazing experiments shows there was clear benefit of N utilization seen in fodder beet treatment especially reduction in urinary N losses of up to 33.2% compared to ryegrass and oats diets. While in the modeling chapter 6, at \$6.00/kg MS in the 2018/19 seasons, it is safe to say the FB & OF (A&S) scenario produced the highest kg MS and at lowest cost among the other scenarios. Generally, no additional feed was purchased for the whole

scenarios and that might be additional reason for the low cost of kg MS production among the scenarios. Therefore, by the objectives of this study it is very feasible and profitable to introduce cash crop (oats) to be grazed in spring after grazing fodder beet in autumn as a sequence on the milking platform. The sequence of oats after fodder beet significantly increased milk production with the lowest cost of producing to factory kg MS, as well as producing the highest forage yield.

7.5. Future research

These studies (3 short-term grazing experiments and 4 long-term FARMAX scenarios) have shown that there is an economic benefit in incorporating FB and oat crops into the milking platform at strategic levels especially on long-term basis. However the practicality of supplementing FB and oats crops on the milking platform in long-term would need to be tested and the cost and time associated with would have to be factored into it. Also, the timing of supplementation (feeding regime) should be experimented aside after morning (A.M.) milking supplementation, because supplements were fed in the morning in the 3 grazing trials conducted. More so, milk fatty acid profile was not captured in the autumn experiment (chapter 4), it will be interesting to examine the CLA of FB in autumn in future work.

With respect to the environment FB diet was very effective in reducing N leaching especially urinary N excretion. However, a similar study in a dry land environment would also be important to investigate how FB and oats crops could be used in an environment less suited to perennial ryegrass to help increase production and provide a buffer in terms of feed shortage and to more volatile environmental conditions that impact on pasture quality and season DM production.

Also, a FARMAX (OVERSEER) study should be conducted to evaluate N losses using FB and oats diets as this was not carried out in these experiments.

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Appendix A

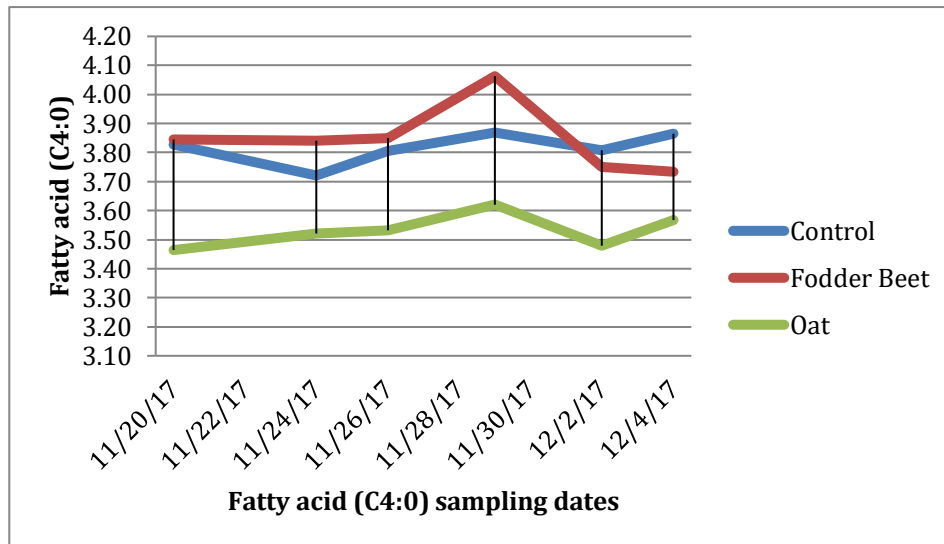


Figure a1. Fatty acid (c4:0) profile of treatment groups.

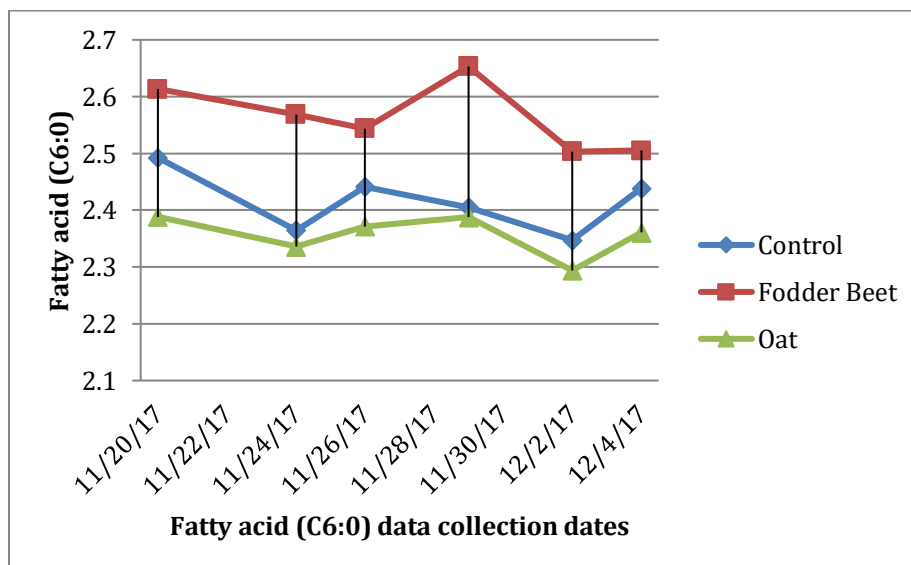


Figure a2. Fatty acid (c6:0) profile of treatment groups

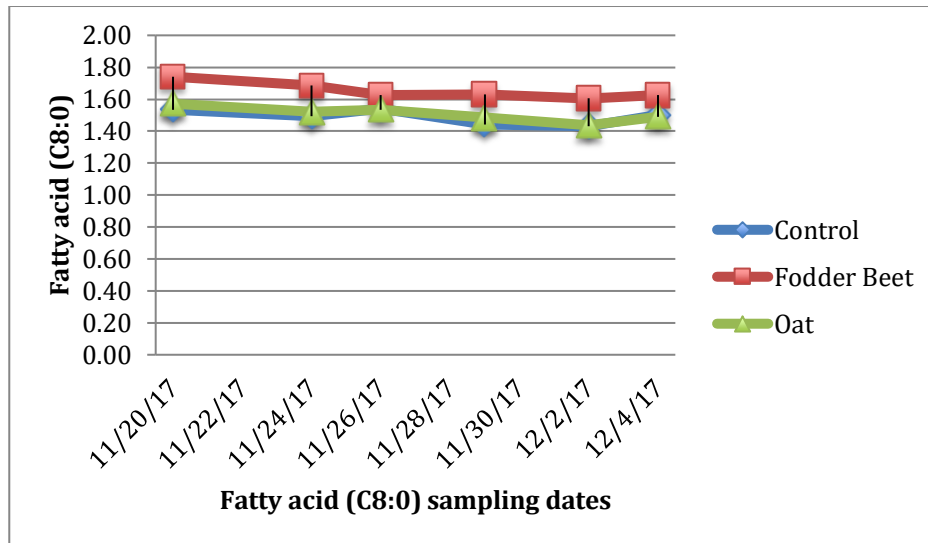


Figure a3. Fatty acid (c8:0) profile of treatment groups.

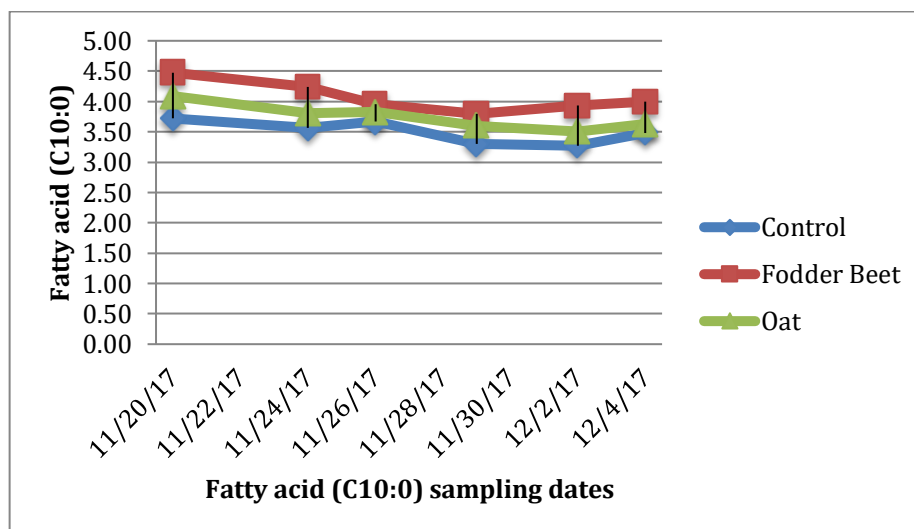


Figure a4. Fatty acid (c10:0) profile of treatment groups.

Appendix B

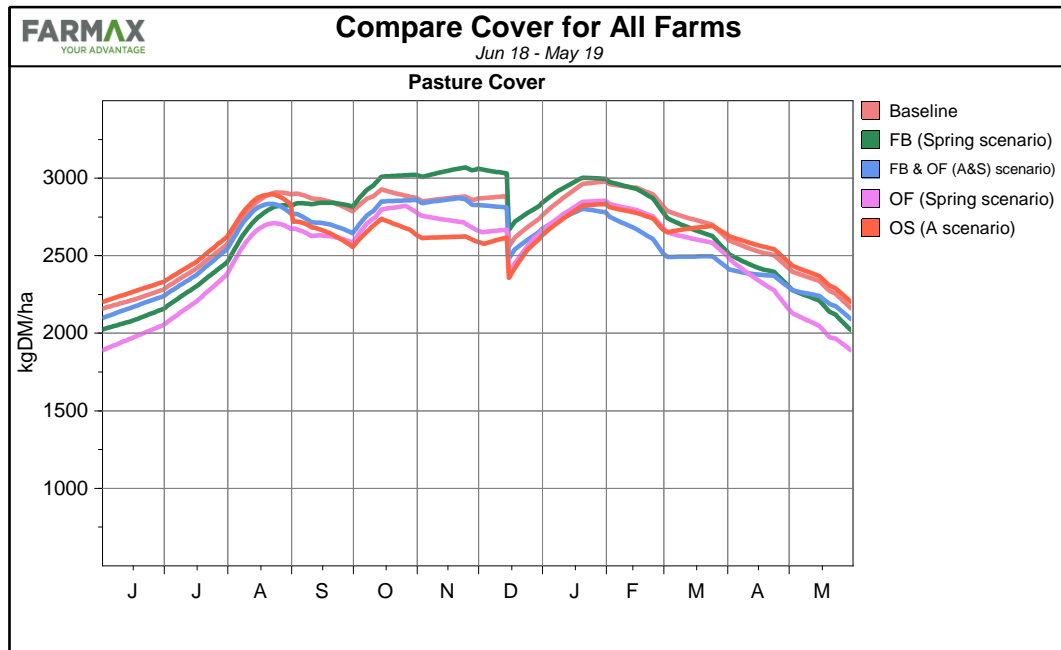


Figure b1. Showing pasture cover for all scenario farms

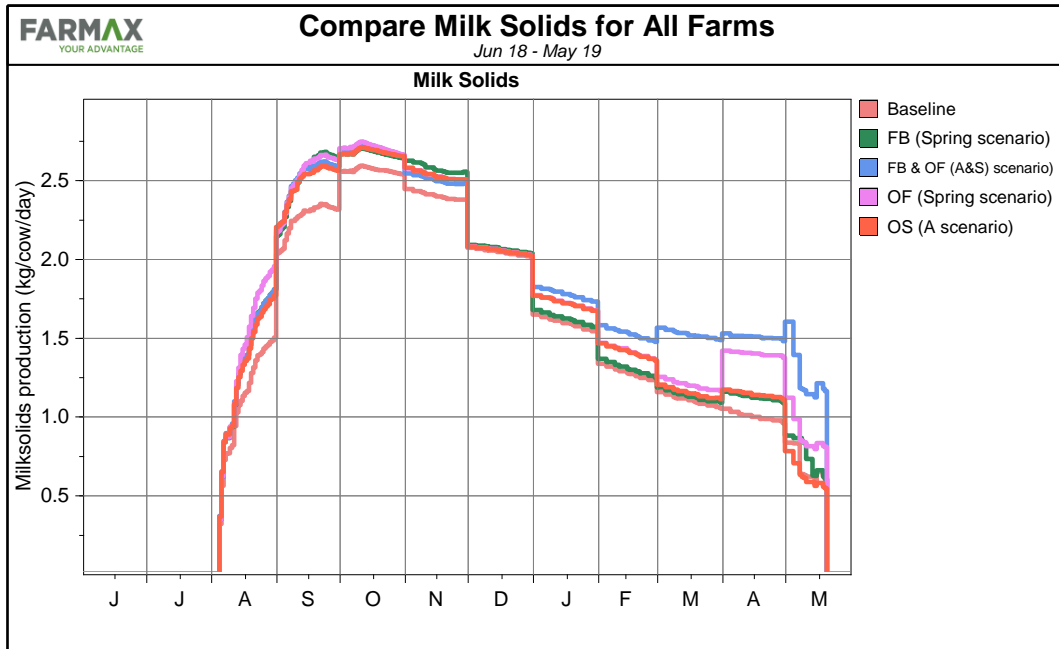



Figure b2. Showing milk solids for all scenario farms

Table b1. Comparing profit and loss for all scenario farms

			Compare Forecast Profit and Loss for All Farms				
			Jun 18 - May 19				
			Baseline	FB (Spring scenario)	FB & OF (Autumn & Spring scenarios)	OF (Spring scenario)	OS (Autumn scenario)
Revenue	Stock	Net Milk Sales - this season	1,732,995	1,712,189	1,926,466	1,819,107	1,799,329
		Net Milk Sales - last season	0	0	0	0	0
		Net Milk Sales - dividend	0	0	0	0	0
		Net Livestock Sales	85,550	96,353	100,568	98,708	98,207
		Contract Grazing	0	0	0	0	0
		Change in Livestock Value	0	0	0	0	0
		Total	1,818,546	1,808,541	2,027,034	1,917,815	1,897,536
	Crop & Feed	Capital Value Change	12,035	-2,492	-2,492	1,570	-2,492
		Total	12,035	-2,492	-2,492	1,570	-2,492
Total Revenue			1,830,581	1,806,049	2,024,542	1,919,385	1,895,043
Expenses	Wages	Wages	205,750	205,750	205,750	205,750	205,750
		Management Wage	109,459	109,459	109,459	109,459	109,459
	Stock	Animal Health	59,475	59,614	59,614	59,614	59,614
		Breeding	19,982	19,982	19,982	19,982	19,982
		Farm Dairy	13,003	13,023	13,023	13,023	13,023
		Electricity	30,451	30,451	30,451	30,451	30,451
	Feed/Crop	Pasture Conserved	32,175	12,870	12,870	12,870	22,559
		Feed Crop	0	57,518	60,000	12,240	0
		Bought Feed	6,405	0	0	0	0
		Calf Feed	4,113	4,090	4,090	4,090	4,090
	Grazing	Grazing	245,565	273,888	273,888	273,888	273,888
		Run-Off Lease	27,982	27,982	27,982	27,982	27,982
		Owned Run-Off Adj.	57,564	57,564	57,564	57,564	57,564
	Other Farm Working	Fertiliser (Excl. N)	164,736	164,736	164,736	164,736	164,736
		Nitrogen	100,152	100,152	100,152	100,152	100,152
		Irrigation	2,340	2,340	2,340	2,340	2,340
		Weed & Pest Control	8,424	8,424	8,424	8,424	8,424
		Vehicle Expenses	48,204	48,204	48,204	48,204	48,204
		R&M Land/Buildings	97,344	97,344	97,344	97,344	97,344
		Freight & Cartage	16,848	16,848	16,848	16,848	16,848
	Overheads	Administration Expenses	21,060	21,060	21,060	21,060	21,060
		Insurance	15,444	15,444	15,444	15,444	15,444
		ACC Levies	9,126	9,126	9,126	9,126	9,126
		Rates	17,316	17,316	17,316	17,316	17,316
Total Farm Working Expenses			1,312,918	1,373,185	1,375,667	1,327,907	1,325,356
Depreciation			97,110	97,110	97,110	97,110	97,110
Total Farm Expenses			1,410,028	1,470,295	1,472,777	1,425,017	1,422,466
Economic Farm Surplus (EFS)			420,553	335,754	551,764	494,368	472,577
Farm Profit before Tax			420,553	335,754	551,764	494,368	472,577
Farm Profit per ha before Tax			1,797	1,435	2,358	2,113	2,020
EFS is a measure of farm business profitability independent of ownership or funding, used to compare performance between farms.							
EFS should include an adjustment for unpaid family labour and management. This can be added to the expense database as management wage.							

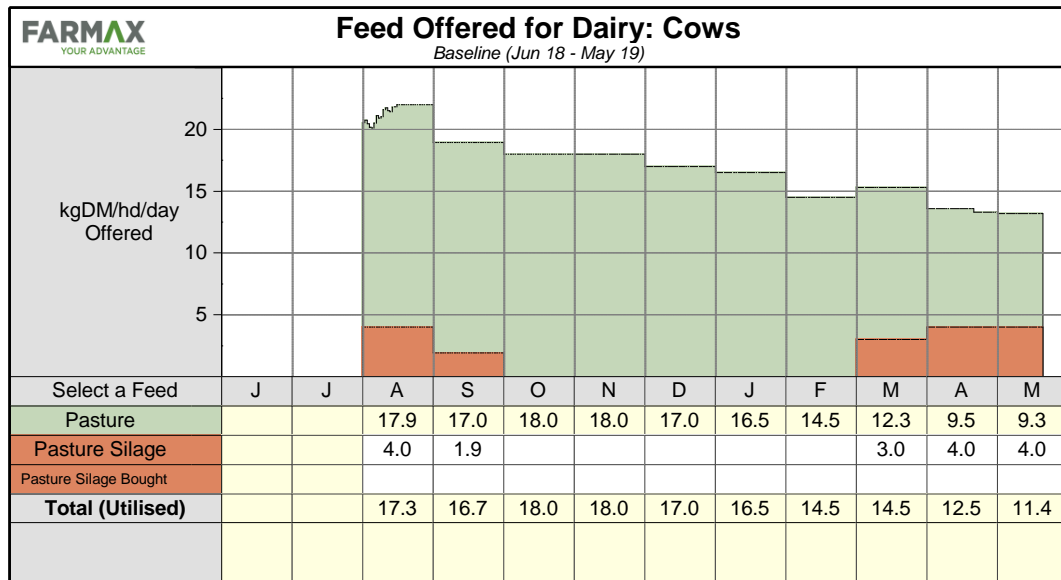


Figure b3. Feed offered and utilized by the baseline scenario